THE NUCLEATION OF THE UNCONTAMINATED ATMOSPHERE

BY CARL BARUS
Hazard Professor of Physics, Brown University

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PREFACE.

The object primarily in view when the present experiments were begun was a continuous record of the nucleation of the atmosphere in a locality relatively free from the habitations of man, and therefore free from nucleations of local and artificial origin. In other words, it was to be determined whether below the fog-limit of dust-free air, *i. e.*, below the least exhaustion at which filtered air condenses without foreign nuclei, the atmosphere contains any nucleation whatever beyond that introduced from terrestrial sources and coming chiefly from the originally ionized products of combustion. An investigation of this kind seemed well worth while, after it had been shown[1] that the nucleation of the atmosphere, even above cities, obeys certain clear-cut laws, showing a marked tendency to reach an enormously developed and sharp maximum in December and a flat but very low minimum in June. The former at least does not in general coincide with the period of maximum cold, and the possibility that some effect from without was superimposed on the local effect seemed sufficiently probable to warrant special inquiry. This was carried out as detailed in Chapters IV and V of the present memoir, in two series of observations, made with similar apparatus, simultaneously at Providence and at Block Island. The two stations, lying about 70 kilometers apart, pass through practically the same meteorological variations of wind and weather; while Block Island, surrounded by a body of water whose smallest radius is nearly 20 kilometers from the center of the island, while one-half of it fronts the ocean, is in the winter at least nearly free from local effect. Leaving the detailed discussion of the results to the chapters specified, it is noteworthy that the average monthly nucleations at both points of observation show the same law of change, though the actual fluctuation at Providence is naturally less salient. The data found at each station prove that the tendency to pass through maxima in December, observed at Providence in 1902-03 and 1903-04, has again unmistakably asserted itself. In addition to this, however, the observations at both stations developed a new and surprisingly pronounced maximum in February as the chief feature in the nucleations of the last winter. Predominating in each of the series of results over the earlier maximum, and holding

[1] Barus: Smithsonian Contributions, Vol. XXXIV, 1905.

for *different* bodies of air, the February maximum at least can not be of local origin; and it is thus in a measure probable that the December maximum also is due to non-local causes. But whether these are the aggregated effects of remote terrestrial sources, or whether they represent an actual invasion of the atmosphere on the part of some cosmic agency, remains to be seen.

The air to be treated in the present series of experiments is, therefore, continually approaching a state of purity so far as foreign admixtures are concerned. Hence the properties of dust-free air, or in practice of filtered air, became increasingly important. It may be proved by aid of the inclosed steam-jet[1] that even dust-free air must be an aggregate of nuclei, whose number grows rapidly larger as their diameter decreases, with a maximum for molecular dimensions; or that size is distributed among the molecules and quasi-molecules of dust-free air in a way somewhat recalling the distribution of velocity among molecules, and that among particles larger and smaller the air molecule represents a condition of maximum occurrence. The fog-limit of dust-free air is thus a variable quantity, depending eventually on the details of the method of filtration, or other process for rendering the air dust-free. In fact, as the fog-limit rises, the coronas for a given exhaustion above the fog-limit increase in aperture, up to a limit. It should always be remembered that the particles or nuclei here in question are very small, even in comparison with ions.

With the object of meeting the state of things in question, systematically, the data in Chapters I, II, and III were investigated, while Chapter VI contains a summary of the work as a whole. The method employed is believed to be a new departure, inasmuch as all results are expressed in terms of the number of nuclei observed per cubic centimeter, so that the nucleations produced are the criteria throughout. To offer conditions sufficiently varied for the experimental work, the nucleation of dust-free air is in these chapters *coarsened* by ionizing it, either by the X-rays or by a weak sample of radium acting through a sealed tube. It thus appears that the ions or fleeting nuclei resulting are also pronouncedly of all sizes within limits and that the increment of nucleation between two definite degrees of exhaustion (*i. e.*, degrees of sudden cooling) above the fog-limit but not too far from it, is greater as the radiation applied from without is more intense. Virtually the gradation of particles is thus more fine-grained or more nearly continuous with the efficient nuclei lying within closer limits of size, as the ionization is more intense.

[1] Barus: Bulletin U. S. Weather Bureau, No. 12, 1893.

Throughout the whole research the important bearing of the solutional or water nucleus[1] on the phenomena of condensation is manifest. If the nucleus is soluble in water, vapor pressure decreases with the continued evaporation of the fog particle, until the decrement of vapor pressure due to increased concentration of the solution is equal to the increment due to increased curvature. The result is a persistent solutional nucleus (water nucleus), necessarily larger than the original nucleus of solute. A great variety of puzzling phenomena like the alternations of efficient nuclei in successive otherwise identical exhaustions, the persistence of fleeting nuclei or ions on solution, the lowered fog-limit of an evaporated corona, etc., thus find a satisfactory explanation.

The final general result to be referred to here is the readiness with which nuclei are produced by the gamma-rays, even after penetrating a centimeter or more of lead, together with the distinction which is thus drawn, experimentally, between these rays and the X-rays. The latter show small penetration, but are so phenomenally active in producing secondary radiation that to a wooden fog-chamber the distance effect for a radius of over six meters between bulb and fog-chamber is relatively neglible. The effect of the gamma-rays, on the contrary, in spite of the remarkable penetration evidenced, for instance, by the nucleation produced, is nearly vanishing when tested by the same nucleation at a distance of but 50 centimeters. Again, within the fog-chamber the distribution of nuclei along the axis is in both cases uniform for all distances (50 cm.) within the range of observation, except when the X-radiation is sufficiently intense to produce persistent nuclei. In this case the curiously pronounced distribution detailed in Chapter I is observed, which seems to show either that the nucleation originates in the walls of the vessel or that, in consequence of secondary radiation, the density of ionization near the walls is such as to promote rapid growth of nuclei in those parts to abnormal sizes. The nuclei in question are over 200 times more persistent than the ions, and if they decay by breaking into like fragments one may estimate that the former are 5 or 6 times larger in diameter than the latter. Persistent nuclei produced by the X-rays require, in fact, but a vanishing pressure difference to induce condensation. They have, moreover, the property of increasing in number if left without interference for a short time after radiation ceases.

In view of the interest which thus attaches to dust-free or filtered air, the nuclear systems of which are throughout small as compared with

[1] Barus: Structure of the nucleus, Smithsonian Contributions, No. 1373, 1903.

the much coarser ions, and show rapidly increasing numbers with decreasing size until the molecular dimensions are reached or even surpassed in degrees of smallness, I have undertaken and have now in progress, under the auspices of the Carnegie Institution of Washington, a systematic research on the properties of filtered air. The fact that the nucleation responds to very penetrating rays, like the gamma-rays of radium, adds additional interest to the inquiry.

In conclusion, it gives me pleasure to acknowledge my indebtedness to Mr. Robinson Pierce, jr., for the efficiency and patience with which he conducted the measurements of nucleation at Block Island, placed in his charge under the very trying mid-winter conditions there encountered. His results are given in Chapter IV. I am further indebted to Miss Lillie L. Scholfield, by whose skill in drawing and experience in editorial work I have materially profited.

My thanks are due finally to the Chief of the U. S. Weather Bureau, for his kindness in placing suitable quarters for observation in the Weather Bureau Building at Block Island at our disposal, and to Mr. Day, the officer in charge of the station, for many courtesies throughout the work.

CARL BARUS.

BROWN UNIVERSITY, *Providence, R. I., July, 1905.*

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CHAPTER I.

RESULTS WITH AN OBJECTIVE METHOD OF SHOWING DISTRIBUTIONS OF NUCLEI PRODUCED BY X-RAYS, FOR INSTANCE.*

1. Introductory.—By passing the X-rays into one end of a long rectangular (virtually tubular) condensation chamber and observing the effect produced after successive different intervals of time by the condensation method, evidence, with a possible bearing on the origin of these nuclei, was obtained. The coronas are distorted and at first occur on the bulb side of the apparatus only. The distribution of nuclei is inferred from the form of the corona.

The experiments described were all made with strictly dust-free air, as both the method of precipitation and of filtration were applied prior to each experiment. Furthermore, as the exhaustions necessitated the use of short lengths of rubber tubing (½, ¾, and 1 inch in bore in the different cases), the amount of sudden cooling obtained does not directly correspond with the pressure difference, δp, owing to the resistance of the tube to the flow of air. The data, δp, thus refer to a given type of apparatus, but they are satisfactory as relations, so long as this is not changed. Furthermore, the pressure difference was so adjusted as to entrap all X-ray nuclei, to the exclusion of the normal, quasi-molecular nuclei of dust-free air, or at least of such nuclei for which a packed-cotton filter is no barrier.

2. Apparatus.—The method was purposely reduced to extreme simplicity, and the apparatus is shown in figure 1. *A B* is the long rectangular condensation chamber of wood impregnated with resinous cement. The front and rear faces are plate glass, through which the coronas may be observed. The other sides are lined within with thick cotton cloth, kept wet, and there is a layer of water at the bottom to insure complete saturation of air. *C* is a stopcock leading to an efficient filter (not shown). Supersaturation is produced by sudden exhaustion at the B end of the apparatus, while the A end receives the radiation from the X-ray bulb, *X*. A large vacuum chamber was placed in connection with the exhaust pipe shown, through a wide stopcock, the details of which need not be explained. The X-rays used were not very penetrating, and were obtained from a soft bulb actuated by

* Much of the experimental part of this chapter was carried out by Mr. [illegible] Pierce, jr., and myself, conjointly.

a small induction coil (4" spark) and 3 to 5 storage cells. Two filters of solidly packed cotton were used, one 7 inches and the other 16 inches long. They were about equally efficient.

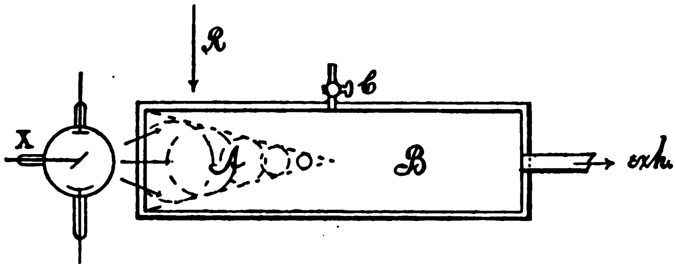


FIG. 1.—Fog chamber, *AB*, with appurtenances and X-ray bulb, *X*.

3. Vertical radiation at one end of the trough, entering through wood.—In the preliminary experiments the bulb was placed so as to radiate into the trough in the position shown at *R*, and kept in action 5 minutes. The effect was then observed by condensation at the pressure difference, $\delta p = 17$ cm., much below the fog limit of dust-free air (section 6). Two results were noted: In the first place, while the coronas obtained with the X-rays in bulky apparatus are usually of the smaller or normal type, the coronas seen in this shallow apparatus were often enormous, transcending the middle green-blue-purple corona (nucleation, $n = 100,000$ per cubic centimeter). Even after two or three subsequent exhaustions, filtered air being added prior to each, large coronas were still in evidence. In the second place, the coronas, and hence the nuclei, were observed chiefly on the A side of the apparatus, under the bulb. Fearing that there might be some direct effect due to induced high potentials, the X-ray bulb was raised 10 and 20 cm. above the trough, with results naturally smaller in magnitude, but of the same kind. The following data may be given:

TABLE 1.—Number of nuclei, n, in thousands per cm.^{3}. $\delta p = 17$ cm. Temperature about 20°. Angular aperture $\phi = s/30$.

	Bulb near trough (2 cm.).						Bulb 10 cm. above trough.				Bulb 20 cm. above trough.	
Time of radiation	5 min.		5 min.		5 min.		6 min.		5 min.		6 min.	
Coronas on—	s	n	s	n	s	n	s	n	s	n	s	n
First exhaustion	(*)	.....	(*)	.....	(*)	.....	3.9	20.5	3.5	15	2.7	6.6
Second exhaustion	5.9	68	.....	.....	6.5	100	2.7	6.6	2.7	6.6	1.9	2.2
Third exhaustion	.....	.....	.....	.....	5.9	68	.....	.....	.....	.....	.....	.....

* Immense, but too diffuse for measurement.

In all cases the first coronas were accompanied by dense rain and fogs, frequently in horizontal strata, so that sharp measurements of aperture are generally out of the question. Moreover, the first condensation is accompanied by turbulent displacement of fog particles and the contents of the receiver are thoroughly stirred up. After filling with filtered air and exhausting again, the coronas are therefore nearly uniform and alike on both sides. In the above table the nucleation produced decreases about as the inverse square of distance, but as the bulb is essentially variable in intensity such a result is not trustworthy.

4. Axial radiation entering one end of trough.—Seeing that it is possible to retain the nuclei on one side of the trough, subsequent experiments were conducted with the X-ray bulb placed as shown at *X* in the figure. Moreover, a smaller interval of radiation was selected to more and more fully exclude the displacement of nuclei by diffusion. The angular diameters (about $s/30$) of the coronas were measured with two goniometers, one on each side (A and B) of the trough, the distance of the coronal centers from the bulb being about 20 cm. and 47 cm., respectively. The following table summarizes the results obtained, remembering that all initial coronas are coarse and blurred and accompanied by copious rain and fog, so that the diameters must be estimated:

TABLE 2.—Number of nuclei in thousands per cm.^{3}. $\delta p = 17$ cm.; angular diameter, $\phi = s/30$.

Time of radiation.	Corona on first exhaustion.				Corona on second exhaustion.			
	A side.		B side.		A side.		B side.	
	s	n	s	n	s	n	s	n
2.5 minutes	4.5	32	2.2	3.3	......	......	......	......
3.5 minutes	4.5	32	2.2	3.3	3.2	11	3.0	9.3
2 minutes	4.0	22	2.0	2.5	......	......	......	......
2 minutes	2.5	5.2	0	0	......	......	......	......

The second coronas are obtained after refilling with filtered air, and it is noteworthy that after the rains of the foggy first coronas fall out (which they do rapidly), there are abundant nuclei left for the next corona. As stated, the nuclei are now uniformly distributed and the coronas persistent, while in the first exhaustion, apparently, certain larger particles captured all the moisture and removed it in a rainy precipitate. The smaller particles are therefore evaporated into water nuclei (as will be shown below), while the initial temperature of the fog chamber is being rapidly regained.

It is to be observed, moreover, that the nucleations on the A and the B sides in these cases are on the average as 9:1, or in a larger ratio, while the ratio of distances is below 1 : 2, because the absorption of the wood is equivalent to a removal of the bulb; hence the density of distribution falls off faster than the inverse cube. The contrast is even greater, because in the 2 or 3 minutes of radiation some nucleation must arrive on the B side by convection and diffusion.

We were originally of the opinion that there is marked absorption of the nucleating power of X-rays, by the successive vertical layers of air from left to right, but it is best not to prejudge the case here.

5. Continued for larger pressure differences.—Several questions now present themselves for immediate decision, viz, whether all the X-ray nuclei have been caught and in how far the exhaustions are below the point of spontaneous condensation of moist air. Accordingly larger pressure differences were applied. Table 3 gives a few examples.

TABLE 3.—Nucleations, n, in thousands per cm.^{3}. Time of exposure to X-rays, 3.5 minutes. Angular aperture $\phi = s/30$.

$\delta p =$	17^{cm}		21^{cm}		31^{cm}	
Side	A	B	A	B	A	B
$s =$	4.6	1.8	3.9	2.1	2.8	2.5
$10^{-3}n =$	35	1.9	27	3.5	11	7.8
Ratio	18 : 1		7.7 : 1		1.4 : 1	

Hence above $\delta p = 21$ cm. for this apparatus, nuclei show themselves on both sides, and the question arises to what extent the normal air nuclei (of dust-free air) have been captured. At $\delta p = 31$ cm. the fog particles condensed on X-ray nuclei probably drop out at once and the persistent corona observed is precipitated on the normal air nuclei stated. At all events, the gradual evanescence of the X-ray effect as δp increases is noteworthy.

6. Condensation dust-free of moist air in the absence of X-ray nuclei—Fog limit.—With the object of finding the pressure difference of exhaustion, δp, corresponding to the lower limit of spontaneous condensation of moist air without foreign nuclei, experiments were first tried with a cock ¾ inch in bore, in the exhaustion tube. The results were identical on the A and the B sides, as follows:

TABLE 4.—Spontaneous condensation in saturated air. Angular aperture $\phi = s/30$.

		24^{cm}	31^{cm}
	$\delta p =$		
	$s =$	2.2	2.7
Repeated,	$s =$	2.4	3.2
"	$s =$	2.1	—
Do., large filter,	$s =$	2.2	3.5
Do.	$s =$	1.9	—
Air over night,	$s =$	2.0	—
Mean,	$s =$	2.1	3.1
	$n =$	3,500	15,500

$\delta p_0 = 22^{cm}$, $n = 0$

This indicates that at a pressure difference of about $\delta p_0 = 22$ cm. for the given apparatus and dust-free moist air, spontaneous condensation with vanishing coronas begins on sudden cooling and that thereafter the coronas increase regularly. This pressure, δp_0, will be usually referred to as the "fog limit."

In corroboration with the preceding, similar experiments were tried with an instantaneous valve, opened with a hammer, and having a clear bore of over 1 inch. The results shown in table 5 were identical on both sides, but unexpectedly irregular, the only explanation for which might seem attributable to a possibly unequal degree of suddenness in opening the valve. But this is not the case; for alternations of large and small coronas in dust-free air, such as are here imperfectly shown, may be kept up indefinitely if strictly identical conditions are retained. Effectively, the large fog particles emit more nuclei, the smaller fewer nuclei for the next condensation in order, everything else remaining the same. The importance of these oscillations about the mean aperture, whether the emission is ionized or not, can not be called in question, as I shall show in Chapter II.

TABLE 5.—Spontaneous condensation of saturated air. Angular diameter $\phi = s/30$.

Press. diff.,	$\delta p =$	19^{cm}	19.4^{cm}	21.4^{cm}	24^{cm}
	$s =$	2.3	3.4	3.3	4.4
Repeated,	$s =$	0	2.1	2.0	2.5
"	$s =$	0	0	3.0	4.3
"	$s =$	0	0	2.0	3.5
"	$s =$	—	0	3.5	3.3
"	$s =$	—	—	2.2	3.3
Mean,	$s =$	0	0	2.7	3.6
	$n =$	0	0	7,600	21,000

$\delta p_0 < 20^{cm}$, $n = 0$

For $\delta p = 19.4$ and below, therefore, no nuclei appeared after thorough cleaning. For $\delta p = 20$ cm. and above, *i. e.*, at a somewhat lower pressure difference than before in consequence of more rapid exhaustion, spontaneous condensation begins. The large coronas are blurred. Hence in neither case will air nuclei be caught at $\delta p = 17$ cm., in the given apparatus.

7. Possibility of producing nuclei by sudden intense exhaustion.*—The condensation of the moist air in the absence of foreign nuclei may be considered as due to the spontaneous nucleation of the air, the available nuclei increasing in abundance as with increasing pressure

* Investigations on the spontaneous condensation of moist air were first suggested by myself, in Bull. U. S. Weather Bureau, No. 12, 1893, pp. 13 and 48. They have since been fully treated in the masterly work of C. T. R. Wilson, Trans. Royal Soc. Lond., vol. 189, pp. 265, 307, 1897; ibid., vol. 192, pp. 403–453, 1899.

differences the sizes of captured nuclei are smaller, until the air molecule itself is approached. It follows, then, that normal dust-free air always contains unstable systems.

Hence the question may well be asked whether very sudden and intense exhaustion may not itself possibly be productive of nuclei. Thus, if an unstable molecular configuration is just about to break down, it is conceivable that the tendency to break down is accentuated by the violent treatment in question.

We made some experiments on this subject, by looking for the presence of ionization under these conditions, using a pressure difference, $\delta p > 30$ cm., by placing a gold-leaf electrometer, properly insulated, in the condensation chamber. The loss of charge in damp air is at first surprisingly small; nevertheless the experiments are very difficult and we were unable to come to a conclusion.

8. Successively increasing times of exposure to X-radiation.—After this digression, experiments were resumed with the apparatus, as shown in figure 1. The pressure difference, $\delta p = 17$ cm., was used throughout, as this is well within the lower limit of spontaneous condensation for the given receiver, while coronas may be obtained with X-ray nuclei for pressure differences even lower than $\delta p = 10$ cm. Such coronas are vague, however, until the rain nuclei are thrown out, and on second exhaustion ($n = 39{,}000$, $s = 4.8$ were usual values after 4 minutes of exposure to the radiation) they are naturally faint.

The immediate incentive to the work of the present section was given by the occurrence of elliptic distortions of coronas, as shown in the following tables:

TABLE 6.—Distorted coronas, Increasing times of exposure to X-rays. $\delta p = 17$ cm. Coronal center 19 cm. (A side) and 46 cm. (B side) from bulb. Angular aperture $\phi = s/30$.

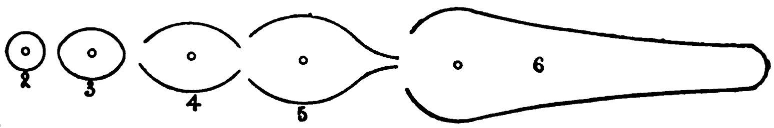
Time,	2 min.	
Side,	A	B
First exhaustion,	$s = 4.5$, elliptic, strong.	1.0 ? faint, circular.
Second exhaustion,	$s = 2.7$, circular.	2.4 circular.
First exhaustion,	$s = 4.6$, elliptic, strong.	0.0
First exhaustion,	$s = 4.6$, elliptic, strong.	0.0

TABLE 7.—Preceding table continued.

Time,	1 min.		2 min.		3 min.	
Side,	A	B	A	B	A	B
$s =$	3.1, round, strong.	0	4.1, elliptic, strong.	0	5.8, ellipse, larger and distorted.	0

On second exhaustion, after refilling with filtered air, the coronas were nearly identical on both sides.

A series of observations was now systematically carried out, unfortunately with somewhat weaker radiation. After 1, 2, and 3 minutes of exposure, respectively, the coronas on the A side were round to roundish (*cf.* figs. 2 and 3), of gradually increasing strength and density, and with rainy precipitation and fog usually marked. There was nothing on the B side even after 6 minutes of exposure. After 4 minutes (*cf.* fig. 4), the corona became spindle-shaped, $s=5.4$ cm. in major axis, accompanied by rain from horizontal layers of fog.



FIGS. 2–6.—A succession of distorted coronas.

After 6 minutes of exposure to the X-rays, the coronas underwent remarkable distortion, becoming gourd-shaped (fig. 5), often with a long, serpentine neck dipping into the B side of the condensation chamber. The length of figure on the goniometer was about 6.8 cm., the outline being orange and the field within greenish. Rain and fog abounded. The coronas on second exhaustion (after adding filtered air) were green-blue-purple, $s=4.9$, $n=42{,}000$, and white-red-green, $s=4.5$, $n=32{,}000$, on the A and B sides, respectively. The experiment was repeated, with like results.

After 8 and 11 minutes of exposure, both the A and the B sides became the seat of the now wedge-shaped corona (*cf.* fig. 6), greenish within and orange in outline. There was much rain and fog.

Figures 2–6 are seen immediately after the exhaustion. A moment later there is a storm-like disturbance in the condensation chamber, accompanied by rain and fog. Hence the distribution of nuclei found on exhaustion is incompatible with a persistent distribution of fog particles. In fact, the first coronas usually fall out rapidly, showing the occurrence chiefly of large fog particles in spite of the corona. The second coronas are circular and persistent, whence a nearly uniform distribution of nuclei may be inferred.

9. Symmetrically graded sizes or numbers of fog particles.—Since the coronas obtained all show an unmistakable tendency to horizontal symmetry with reference to the longitudinal axis of the condensation chamber, the nuclei to which the coronas are due must either originate in, or else be absorbed by, the top and bottom of the apparatus. Nuclei originating or lost at the front and rear faces are nearly uniformly distributed normal to the line of sight and produce circular coronas. Nuclei originating or lost at the left-hand end of the chamber will additionally distort the corona, and such distortion is clearly in evidence, apart from the one-sided position of the coronas.

Mere inspection of the coronas (figs. 2–6) shows that they are larger for fog particles near the axis, and smaller for particles near the top and bottom of the condensation chamber. Hence it is next necessary to explain that the details of the distorted coronas observed actually correspond with a gradation of the number of *effective* or available nuclei, from the axis outward on all sides. In the case of linearly graded fog particles increasing in diameter, δ, from bottom to top, it appears that the equation of the apertures, s, of the loci* of like color of the corona is

$$s = -\frac{\delta_0}{a \sin \phi}\left(1 - \sqrt{1 + \frac{2 a s_0 \sin \phi}{\delta_0}}\right),$$

where s_0 is the aperture for the particles of diameter, δ_0, in the horizon or plane of sight, and δ the angle in polar coordinates between the radius vector to the part of the corona in question and the horizontal, the origin being at the center of the corona. Finally $\delta = \delta_0 - ah$. Such coronas when the gradation becomes marked are *campanulate* in outline, finally becoming basin-shaped.

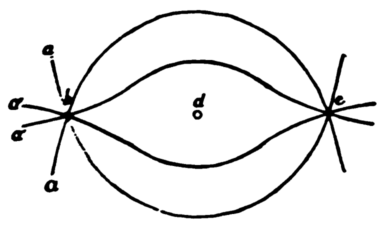


FIG. 7.—Computed curves.

In the present case, however, there are two symmetrical distributions of this kind, *i. e.*, increasing diameters of fog particles from the axis of the chamber toward the top and the bottom. Hence pairs of intersecting curves, two examples of which are given in figure 7 ($a' > a$), show the coronas to be anticipated, if the remote parts beyond b and c of the corona are ignored and only the stronger curves surrounding the spot of light, d, admitted. In other words,

* Barus: Am. Journ. Sci. (4), XIII, p. 309, 1902.

as the distance, *b c*, varying with the number of axial nuclei and the distribution constant, *a*, increases, all the figures, 2, 3, 4, 5, 6, may be logically evolved.

On the left-end face, moreover, there would be special interference with the distribution of nuclei giving rise to the corresponding distortion seen in the coronas. Further distortion due to the decrease from left to right of the intensity of the radiation must also be apparent, and the gradient of distribution will be slightly altered by diffusion. One may note that if anything issues from the walls of the vessel, it comes as abundantly out of the water below as out of the wet cloth above.

10. Possible origin of nuclei at walls of receiver.—As has already been suggested, the observed gradation of fog particles may result from the (real or virtual) evolution of effective nuclei at the top and the bottom of the apparatus, in consequence of the impact of X-rays on those parts. There is much electric evidence against such an explanation; nevertheless it is worth a brief examination, particularly as it includes the effect of secondary radiation to be discussed below (Chapter III).

The enormous coronas which have been obtained with the above (shallow) apparatus, as compared with the small coronas seen in the cases of more bulky apparatus, is in keeping with this view. Again, the rapid decrease of the nucleating power of the X-rays might to some extent be associated with the increasing obliquity of the rays, but no evidence of this was found.

The observed distortion of coronas is clearly due to a gradation of nuclei, either as to size or number, or both. If efficient nuclei issue from the top and bottom, they must be present in greatest number near those parts of the apparatus, and consequently the largest diameter of coronas should apparently be found there. But if the largest number of effective nuclei is present near the top and bottom, the tendency to growth by cohesion will also be most marked in those regions. Hence, with this admission, the largest nuclei must be looked for nearest the top and bottom, while the gradation in size decreases regularly toward the axis. The large nuclei, therefore, may be sufficiently numerous near the walls to capture all the available moisture on condensation, leaving the small nuclei without a load of water and unable to appreciably descend. Hence the marked rain effect, the rapidity with which the first coronas usually drop out, the turbulent motion which succeeds condensation, the occurrence of large persistent coronas on second exhaustion even after the first coronas have quite dropped out, etc., are all in a measure accounted for.

Finally, one may note that secondary radiation (the importance of which I at first underestimated) issuing from the top and the bottom of the condensation chamber would accentuate the present effect, or even wholly replace it.

Thus it seems not unreasonable to infer that nuclei are produced by the impinging X-rays in much the same way in which they are produced by high temperature (ignition), or by high potential; and the question arises whether the nuclei thus put in evidence may not be associated with the electrons to which the cohesions between the molecules may be ascribed.

11. Absorption of ions at walls of receiver.—If the nuclei due to the ionization of air by the X-rays are absorbed at the walls of the receiver* a diffusion gradient will be established, resulting in a decreasing number of nuclei from the axis outward, a distribution the reverse of the preceding. The observed distortion will therefore here be due to a gradation in the numbers of nuclei.

One difficulty in the present instance seems at first sight to be fatal; for no reason is suggested why the coronas on second and third exhaustion do not eventually show flower-like distortion, which they never do. In other words, it is here tacitly assumed that only the nuclei in the nascent state, as it were, are appreciably diffusible, while the nucleus is relatively a fixture. It will be shown in Chapter III, however, that on second and third exhaustion all the nuclei have probably been converted into solutional water nuclei by evaporation, so that the difficulty in question is not serious.

12. Summary.—To decide between these hypotheses it is necessary to guide the X-rays by screens, suitably placed both on the inside and the outside of the apparatus; but these experiments will, in the succeeding chapters, lead to results much too diffuse and complicated in character to be summarized at present.

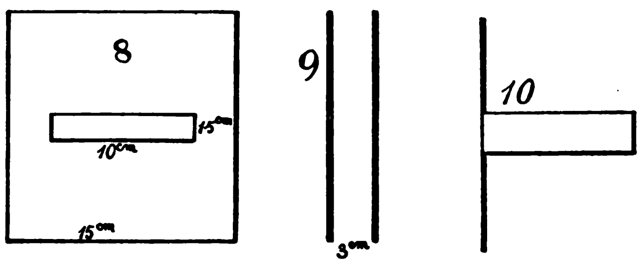
Here there is room only for a final remark. Whenever nucleation and ionization are associated as the outcome of any process (physical or chemical), the former is generated proportionally to the latter, in such a way that each is produced at its own rate depending on inci-

*A number of similar cases have been worked out in Smithsonian Contributions, No. 1309, 1901, "Experiments with ionized air;" and ibid., No. 1373, Chapter V, 1903.

dental conditions. This is best worked out with water nuclei. The subsequent life-history of the nucleation and the ionization is distinct, nuclei, when produced by intense radiation as above, being surprisingly persistent, ions by contrast characteristically fleeting. Hence it seems to me to be best in keeping with all the data in hand to regard the nucleation as the product which owes its growth or origin to the expulsion of the corpuscles representing the concomitant ionization. Ignition and high potential nuclei, X-ray and radiation nuclei in general, phosphorus and water nuclei, produced throughout in strictly dust-free air, all admit of this account of their occurrence and properties. There is no observable case of a process producing ionization without nucleation, although there are many cases of nucleation free from ionization.

13. Tentative experiments with lead screens, inside and outside of the fog chamber.—These experiments were made in large number; but owing to the variability of the X-ray bulb and the action of the coil, as well as the difficulty of realizing truly geometric conditions with X-radiation, they are not satisfactorily conclusive. It will be seen in the following chapters that results like the present can not in any case be more than preliminary in character.

The screens were lead plates with holes cut in them, or lead tubes soldered to the edges of the holes normal to the plate. They were placed between the X-ray bulb and the A end of the fog chamber to guide the radiation.



FIGS. 8–10.—Forms of lead screens.

In case of the observations 1 to 6, the screen was in the shape of figure 8, with a horizontal slit 10 cm. long and 1.5 cm. wide, stretching nearly across the end of the fog chamber. Often screens of this kind were adjusted 2 to 3 cm. apart, as shown in figure 9. The screen was earthed and the bulb placed as near it as practicable.

TABLE 8.—Miscellaneous experiments, chiefly with screens. Long fog chamber, vol. 13,000 cm.[3]. δp usually 17–18 cm. Coil with 4 cells. Observations at middle of chamber, 29 cm. from end.

No.	Exposure.	Corona.	s.	Screen.	Remarks.
	Min.				
1	10	Round		Lead, with slit	Corona strong; clear.
2	5	.....do		.....do	Corona very small.
3	11	Oval?	3.6	.....do	Corona not sharp.
4	10		0.0	Same, doubled	No corona.
5	7	Oval	4.0	Screen removed	
6	10	Round	3.0	Double-slitted screen	
7	14		0.0	Lead, with tube, 2.5 cm. diameter, 8 cm. long.	
8	7	Oval	6.1	Screen removed	On both A and B sides.
9	12		0.0	Lead, with tube (axial)	Corona just visible.
10	11		0.0	Do., tube directed to bottom.	
11	11		0.0	Tube axial	Just visible; forms gradually.
12	11		0.0	Do., bulb plate normal.	
13	12	Clear	(?)	Tube directed to glass.	Small corona.
14	10	Oval	5.0	Screen off	Large diffuse corona; strata.
15	20	Round	4.0	Lead, with tube, 3.5 cm. diameter, 4 cm. long.	Strong corona; larger in middle of apparatus.
16	11	.....do	3.0	.....do	Clear corona; little fog.
17	11	.....do	3.0	.....do	Clear corona, oval on A side.
18	10		0.0	.....do	Coil works badly.
19	10		(?)	.....do	Coil works badly (?). Corona just appears.
20	10	Round	(?)	.....do	Small coronas throughout chamber.
21	11	.....do	(?)	.....do	
		Recent results,* with more powerful coil (6 cells) $\delta p = 16.7$.			
					Second corona—
22	3	Distorted; fog and streamers.	A side full	Disk of lead 3 cm. in diameter over center.	$s_2 = 3.4$.
23	5	Campanulate	.....do	.....do	$s_2 = 4.2$.
24	5	Streamers	.....do	.....do	$s_2 =$ large.
25	5	Round	3.6	Hole (2.5 cm.) in lead plate.	$s_2 = 1.9$.
26	5	.....do	2.4	.....do	$s_2 = 1.1$.
27	3	Streamers†	A and B sides full.	Screen off	$s_2 = 5.9$.
		$\delta p =$	18.5	Six cells	$s_2 = 2.6$.
28	4	Fine oval	6.4	Lead tube axial	Corona on both sides.
29	4	Round	2.5	Lead tube at top	
30	4	Roundish	4.5	Lead tube axial	
31	4	Round	3.5	Lead tube at top	
32	4	Open on top	1.6	Lead tube at bottom	Corona horseshoe-shaped.
33	4	Roundish	3.0	Lead tube axial	
34	4	.....do	3.5	.....do	Coil improved.

* All lead screens earthed. † Campanulate on B side.

Since the front and rear faces of the fog chamber can only contribute a distribution of nuclei corresponding to round coronas with the given line of sight, while the lead cuts off most of the efficient radiation from the top and bottom, round coronas should appear if the nuclei come out of the walls. This was, in fact, the case in the first and second experiments, where clear, round, strong coronas were observed; the third observation, however, leaves the question in doubt.

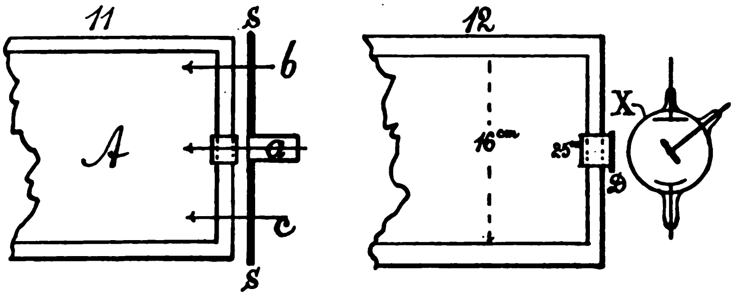
Similarly conflicting results were obtained with the screen (fig. 9), the radiation being weaker in view of the greater distance of the bulb from the fog chamber and the more efficient screening. With the lead plates removed, the usual phenomena (oval coronas) appear; but throughout, the contrast is not sharp enough for definite decision.

Long lead screens placed horizontally within the fog chamber opposite the slit in the external screen, as at *A* in figure 11, did not stop the radiation. Elliptic coronas were observed around the trace of the screen as a minor axis, precisely as if the internal screen were absent. Hence either diffusion or secondary radiation must be very active throughout the exposure.

In experiments 7 to 21 the lead screen, figure 10, was a broad flange on a lead tube, 2.5 cm. in diameter and 4 cm. or 8 cm. long. The X-radiation was usually directed axially, sometimes obliquely, against the walls. With the tube 8 cm. long measurable coronas were not obtained, no matter whether the rays passed axially through the fog chamber or not. In the absence of the lead screen, or when the lead screen was replaced by a thin continuous aluminum screen, the nuclei often filled the chamber on the A and the B sides and the coronas were large. This would again be accepted as evidence favoring the view that the nuclei come out of the walls; but when the radiation is directed against these walls through the tube there is no appreciable increment. Thus the experiments remain inconclusive.

The work was now continued by cutting down the tube to 4 cm. in length. The strong coronas obtained were clear and round, with very little fog. At times they seemed to be largest in the middle of the apparatus. Slight oval distortion appeared on the A side near the bulb only. The general absence of distortion when the impact of X-rays is cut off from the top and the bottom again is favorable to an origin of nuclei in those parts. Failure of the experiments 18 to 21 is attributable to the spark gap of the coil; but here coronas were often seen throughout the length of the fog chamber, very gradually decreasing in size from A to B. When the eye was moved rapidly in this direction, the coronas were found to lie within a triangle, symmetrical with respect to the axis of the fog chamber, and the diameter of the coronas vanishes at the apex of the triangle, near the middle of the chamber, as suggested in figure 1.

14. Continued, with change of apparatus.—In these experiments a more powerful coil was used, actuated by six storage cells and a Foucault interrupter. The object first aimed at was a contrast of the rays entering the fog chamber axially with the oblique rays which strike the walls. Accordingly, in experiments 22 to 24 the entrance of radiation into the axial part of the end of the fog chamber is cut off by a lead disk, *D*, figure 12, about 2.5 cm. in diameter. In comparison with experiment 27, where the screen was removed, the coronal effect for the disk is somewhat weaker, but throughout of the same nature, with campanulate or spindle-shaped coronas filling more than half of the length. Much rain and fog were present, and crimson-colored streamers stretched horizontally and symmetrically, bow-shaped (convexity outward), from end to end. The first coronas (s_1) are not measurable, but, after the first fog particles have fallen out, the second (s_2) are quite so, being round and clear.



FIGS. 11-12.—Fog chambers with screens and X-ray bulb.

The disk was now removed and a lead screen, *S*, figure 11, with a hole about 2.5 cm. in diameter, placed over the end of the fog chamber, with the X-ray bulb placed as before. To make the wood more transparent a waxed cork was inserted, giving free entrance to the axial rays. All screens were earthed as usual. Experiments 25 and 26 show the results. The contrast with the preceding is marked. The coronas are round, and in the first exhaustion show apertures (s_1) decidedly smaller than the coronas obtained in the second exhaustions of the preceding cases. True, the amount of radiation entering the fog chamber is much larger for the case of the disk than for the case of the perforated screen; but it nevertheless follows that the axial rays, even if entering under favorable conditions, can not be specially efficient. Rays which have penetrated the fog chamber obliquely and impinge on the top and bottom are responsible for nearly the whole of the dense fog usually observed.

In further experiments, work with the flanged lead tube (2.5 cm. in diameter, 4 cm. long, figure 10, center of bulb 5 to 6 cm. from the end of the fog chamber and about 8 cm. from the inner face) was resumed and successively placed in positions, *a* (axial), *t* (radiation grazing the top surface), *b* (radiation grazing the surface of water below, as seen in figure 11), the screen being moved with the bulb. The experiments

28, 30, 33, and 34 are deficient from the gradual loss of strength of the X-ray bulb; but the data for s in the axial case are nevertheless larger than for the cases where the rays grazed the top or the bottom of the fog chamber. In the latter, the corona is particularly small and open on top, showing the absence of nuclei in the upper strata of the air of the fog chamber. Thus the endeavor to directly call out the nuclei from the top or the bottom of the fog chamber has again failed.

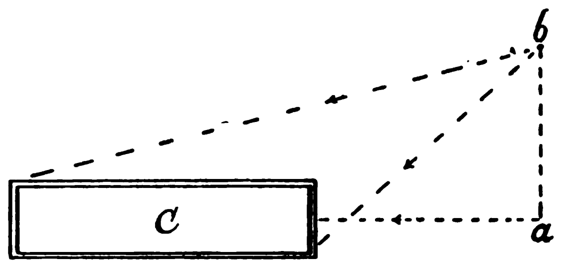


FIG. 13.—Fog chamber with axial and oblique radiation.

A final test on the effect of the walls was made in a somewhat different manner by placing the bulb at a distance of 80 cm. from the chamber C, figure 13, at first axially, as shown at a, and then in the raised position, b. In the first instance the rays pass through the least surface of wood and the incidence within is grazing; in the second (nonaxial), the rays pass through a much larger surface of wood and the incidence is at a large angle. Table 9 shows the results in the two cases to be identical, barring increased distance and the tendency of the bulb to lose efficiency in the lapse of time. In the present case, however, the nuclei are of the fleeting kind discussed in the chapters below, and comparison with the above persistent nuclei is not at once permissible.

TABLE 9.—Comparison of axial end oblique rays $\delta p = 23.3$ cm.

Position of bulb.	s.	Remarks.
Axial	3.6	Distance, 80 cm. from bulb to chamber (inside) axially. Raised position 35 cm. above axis. Rays off, $s = 0.0$ (fig. 13). Observations made during exposure to X-rays.
Raised	3.6	
Raised	3.5	
Axial	3.6	
Raised	*5.3	Distance, 40 cm.
Axial	4.6	
Axial	†4.0	Distance, ‡80 cm. $\delta p = 24.8$ cm. Exposure, 3 min.
Raised 35 cm	†4.0	
Raised 55 cm	†3.8	
Raised 55 cm	†3.8	
Axial	3.9	

* Periodicity. Difference due to X-ray bulb. †Air $s = 1.5$. ‡ $s_2 = 1.0$.

15. Conclusion.—Generally, when the bulb is close to the end of the chamber, the coronas obtained after a short exposure are all roundish, but taper from a large size near the bulb to the vanishing diameter or apex, figure 1, near the middle of the fog chamber, with all intermediate gradations of aperture in corresponding intermediate positions. The pressure difference, δp, applied is thus more and more in excess of the fog limit as the line of sight is nearer the bulb. Beyond the apex the pressure difference used is below the fog limit. Smaller nuclei occur throughout the chamber, but they are probably more and more fleeting in character. The colloidal nuclei of dust-free air are always present. The number of nuclei within the given range of condensation, *i. e.*, above a certain lower limit of diameter, increases with the intensity of the ionization, axially as well as transversely. If the exposure is prolonged and the radiation sufficiently intense, the nuclei are everywhere within the given pressure difference, but the axial excess of efficient nuclei is retained. Beyond this, the endeavor to come to a decision as to the origin of the persistent nuclei on the basis of the above experiments seems as yet premature; for in addition to the hypothesis which refers them to the impact of X-rays on the walls of the vessel, the diffusion hypothesis, the effect of secondary radiation within the vessel (such radiation outside of the vessel produces fleeting nuclei only as will be detailed in Chapter III), etc., there is something to be said in favor of the spontaneous production of water nuclei in the presence of the intense X-radiation arriving at any point from both primary and secondary sources.

CHAPTER II.

NUMBERS AND GRADATIONS OF SIZE OF NUCLEI IN DUST-FREE AIR.

EXPERIMENTS WITH DUST-FREE AIR NOT ADDITIONALLY ENERGIZED.

Alternations of large and small coronas observed in case of identical condensations produced in dust-free air saturated with moisture.

16. Apparatus.—By dust-free air I mean air which has been passed through a packed-cotton filter. My filters are 16 inches long, conical, tapering from about 2 inches in diameter at the large end to about ½ inch at the other. They contain absorbent cotton rammed in from both ends and kept in place by wire. When filtered air is required, the stopcock is only just opened so that influx of dust-free air may be extremely slow.* This insures proper filtration and does not interfere with the saturation of the air in the fog chamber. In this section condensation was produced in a long glass cylinder, 16 inches from end to end and 5½ inches in diameter, placed horizontally and normal to the line of sight. It contained a rectangular framework of copper wire covered with wet cotton cloth, except on the two opposed broadsides through which the coronas were observed. The distance between the bottom (water) and the roof of the rectangular framework was about 9 cm. The provisions for keeping the air saturated are thus ample.

The vacuum chamber was a large boiler of galvanized iron, having a capacity, V, of over 100,000 cc., while the capacity, v, of the condensation chamber is about 6,700 cc., so that the volume ratio, v/V, is but 0.063. The two chambers are connected by about a foot of rubber tubing over 1 inch in bore, usually containing a 1-inch plug gascock. An instantaneous clapper valve of the same dimensions and opened with a hammer was often used for comparison.

Later the glass fog chamber was advantageously replaced by one of waxed wood (see fig. 1, Chapter I), with the opposed sides, through which the coronas were observed, made of plate glass. The internal dimensions in this case were $55 \times 12 \times 20$ cc., and the volume ratio, v/V, in connection with the vacuum chamber, about 0.13. There is difficulty, however, in using a chamber of this kind for the present purposes, where even very small leakage is a serious discrepancy.

* When the rate of filtration is gradually decreased until it all but vanishes, results of special interest are observed which will be detailed elsewhere.

17. Manipulation—Fog limit.—The experiments were conducted as follows: Having selected a suitable pressure difference above that at which condensation in dust-free air just begins (usually termed the "fog limit" in the present paper), the dust-free moist air in the closed condensation chamber at atmospheric pressure is suddenly exhausted and the corona measured. After all fog has subsided the exhaustion cock is closed and the filtered air very slowly admitted. The operations are then repeated, allowing time (about 2 to 3 minutes) for saturation. Under all circumstances the treatment for large and small coronas was identical.

In the given apparatus condensation in dust-free moist air began at the pressure difference, $\delta p = 22.5$, corresponding to the volume expansion of about 1.43. The pressure difference usually applied in the experiments was $\delta p = 31.2$, and the volume expansion 1.72.

18. Alternations of large and small coronas (periodicity of inferior and superior coronas).—The small coronas are usually sharp, but the large coronas appear blurred and filmy, accompanied with much rain. Remembering that all operations are conducted in a way strictly the same, table 10 (pp. 19–20) shows the coronas seen in the successive exhaustions. The angular diameter or aperture is $\sin \phi/2 = s/60$, or nearly $\phi = s/30$. The eye at the goniometer was about 40 cm. from the axis of the condensation chamber (placed as close as possible to insure clearer vision) and the source of light 250 cm. beyond it. Observations were made along the axis of the cylinder, placed horizontally. The number of nuclei per cubic centimeter of the exhausted air will be denoted by n, while N shows the number per cubic centimeter of air at normal pressure. The reduction of n to N where it is not essential will often be omitted.

In the case of 2-minute periods between the exhaustions the periodicity is maintained without exception (fig. 14). For brevity let the smaller coronas be called *inferior*, the larger coronas *superior*. Frequently a very small inferior corona evokes a relatively large superior corona, or larger inferior coronas are followed by smaller superior coronas; but this is not always the case. As a more general rule, if the aperture is intermediate between the inferior and superior coronas, the succeeding corona is of the same size, and oscillation terminates. In part III, for an accidentally more rapid influx than the exceedingly slow influx of filtered air in the earlier parts of table 10, this is initially the case, but the oscillation is soon reestablished. In part IV, the water was shaken so as to wet the glass sides of the chamber, but without effect on the oscillation (fig. 15). In part V of table 10, the original periodicity is again wiped out by accidental influx of much air through the filter. Periodicity thereafter fails to reappear, as is also the case in parts VI and VII. Similar cases occur in parts VIII, IX, and X. The mean apertures at 25°, 20°, and 11° do not differ sufficiently to indicate a temperature effect above the value of the incidental errors.

TABLE 10.—Periodicity in the condensation of dust-free air. Plug valve. Pressure difference, $\delta p = 31.2$ cm. Temperature = 25° C. Glass clear, no shaking of water needed. Two-minute periods between exhaustions. Slow influx. Cylindrical fog chamber, volume ratio $v/V = 0.063$.

Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.
Part I.			Part II—Continued.			Part III.		
1	*1.7	2.3	5	2.9	9	‡21	3.9	59
2	5.7	73	6	6.4	97	22	3.8	58
3	2.5	6.1	7	3.0	10	23	3.1	47
4	6.4	97	8	6.6	106	24	5.8	88
5	2.9	9.6	9	3.1	11	25	3.1	47
6	6.6	106	10	6.4	97	26	5.2	79
7	3.2	12.6	11	3.2	12.6	27	3.1	47
8	....	....	12	6.6	106	28	6.3	96
	†2.9	9	13	3.2	12.6	29	3.4	52
			14	6.3	93	30	5.9	90
Part II.			15	3.1	11			
			16	6.6	106			
1	2.9	9	17	3.5	16.7			
2	6.2	90	18	5.5	67			
3	3.4	15	19	3.0	10			
4	5.3	59	20	6.9	122			

*After 16ʰ (left over night). †After 25ᵐ.
‡Accidental rapid influx. Note the rise of inferior coronas.

TABLE 10, continued.—Slow influx; water shaken; fog in glass; 20° C.; $\delta p = 31.2$.

Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.
Part IV.			Part V.			Part VI.—Temperature, 11° C. $\delta p = 31.2$.		
*1	1.7	2.3	1	2.3	3.5	†1	4.6	39
2	5.2	56	2	5.7	73	2	4.6	39
3	2.8	7.9	3	3.0	10	3	4.6	39
4	5.3	59	† 4	4.1	26			
5	2.4	5.0	5	4.2	29	Part VII.—Temperature, 11° C. $\delta p = 29.8$.		
6	5.9	82	6	5.3	59			
7	3.0	10	7	5.2	56			
8	5.7	73						
9	2.9	9.0				† 1	3.9	23
10	5.5	67				2	4.7	42
11	2.8	7.9				3	4.6	39
12	5.6	70				4	4.7	42
13	2.8	7.9						
14	5.4	64						
15	2.8	7.9						

* Left after 15ʰ. † Periodicity absent in the first case after accidental influx.

TABLE 10, continued.—24–25° C. Cylinder. $\delta p = 31.2$. Promiscuous results.

Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.
Part VIII.			Part IX.			Part X.		
1	*3.0	10	1	†3.3	14	1	‡3.5	17
2	4.9	49	2	5.3	59	2	5.2	56
3	4.5	36	3	3.0	10	3	2.5	6.1
4	4.7	43	4	5.7	73	4	6.1	85
5	4.7	43	5	2.7	7.9	5	**2.8	7.9
			6	5.7	73	6	5.4	64
			7	2.7	7.9	7	4.2	29
						8	5.2	56
						9	4.8	46
						10	4.9	49
						11	4.9	49
						12	4.8	46

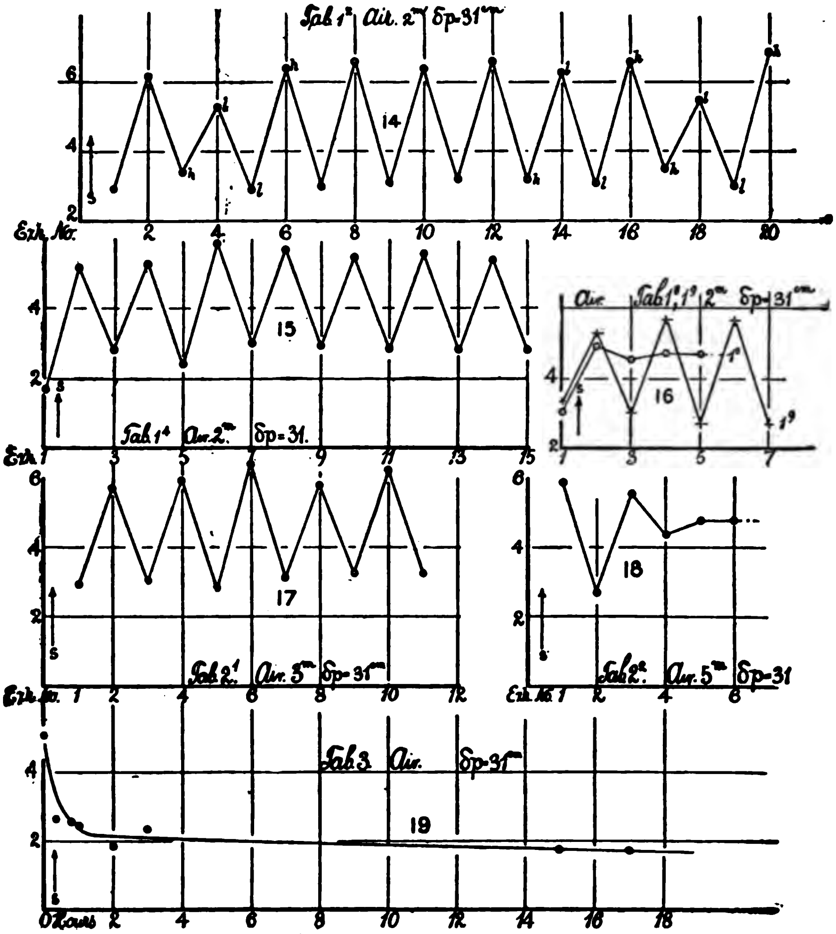
* After 24 hours. † After 15 hours. ‡ After 2 hours.
** Apparatus (water) shaken, thereafter glass dull.

In table 11, for 3-minute periods between the exhaustions as a safeguard against partial saturation, the same oscillations reappear (fig. 17). Very small inferior coronas are again followed by the larger superior coronas. On the other hand, the larger superior coronas usually precede larger inferior coronas, as above. The case of 5-minute periods between the exhaustions (fig. 18) begins with marked periodicity, after which, however, cotemporaneously with the deposition of fog on the glass between observations, periodicity vanishes.

TABLE 11.—Periodicity in the condensation of dust-free air. Plug valve. $\delta p = 31.2$. Temperature = 25° C.

Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.	Exhaust No.	s.	$n \times 10^{-3}$.
Three-minute periods between exhaustions.						Five-minute periods (and longer) between exhaustions.		
1	2.9	9	7	3.1	11	1	59	82
2	5.7	73	8	5.8	76	2	2.7	7.9
3	3.0	10	9	3.2	12.6	3	5.6	90
4	5.9	82	10	6.2	90	4	*4.4	46
5	2.8	7.9	11	3.2	12.6	5	*4.8	59
6	6.4	126				6	*3.8	61

* Glass fogged during the interval.



FIGS. 14–18.—Graphs showing the alternations of the apertures (s) of coronas in non-energized dust-free air. The abscissas show the numbers of the successive exhaustions; the ordinates are nearly as the cube roots of the number of efficient nuclei.

FIG. 19.—Decay of the nuclei examined in the lapse of hours.

Table 1, referred to in figs. 14, 15 and 16, will be found as table 10, p. 19.
Table 2, referred to in figs. 17 and 18, will be found as table 11, p. 20.
Table 3, referred to in fig. 19, will be found as table 12, p. 22.

19. Effect of lapse of time on the nucleation of dust-free air imprisoned in the fog chamber.—The 5-minute periods in the preceding table, or figure 18, do not markedly diminish the aperture of the coronas. Larger periods of waiting are very effective, as is seen in table 12, where v/V shows the volume ratio of fog and vacuum chambers. The measurements refer to an initial large corona of say $s=5$ cm.; but as this can not be measured without destroying the nuclei, the present data merely show the usual occurrence of inferior coronas in the lapse of time (fig. 19). In 15 hours the aperture is reduced to one-third and the nucleation possibly to one-thirtieth. Certain relatively high results at the end of the table seem to be referable to the presence of radium in the laboratory, but no definite statement can be made.

TABLE 12.—Evanescence of nucleation of dust-free air in lapse of time.

Glass fog chamber. $^*v/V = 0.063$.									Wooden fog chamber. $^*v/V = 0.13$.			
δp.	Temp.	Time	s.	$n \times 10^{-3}$	Temp.	Time	s.	$n \times 10^{-3}$	δp.	Time	s.	$n \times 10^{-3}$
31.2	°C.	h. m.			°C.	h. m.			°C.	h. m.		
	11	0 0	(4.6)	(70)	20	0 0	(5.5)	(67)	†33.0	0		
		20	2.6	3.9		1 0	2.4	5.0		24	3.0	10.3
	20	0 0	(5.2)	(56)	23	0 0	(5.5)	(67)		0	3.4	15.6
		15 0	1.7	2.3		3 0	2.3	4.1		0	3.3	14.5
	20	0 0	(5.2)	(56)	25	0 0	(5.5)	(67)				
		2 0	1.8	2.4		16 0	1.7	2.3				
	20	0 0	(5.5)	(67)		24	3.0	10				
		0 50	2.5	6.1		15	3.3	14				

* Volume ratio of fog and vacuum chambers. † Vacuum chamber disconnected.

The marked occurrence of inferior coronas in the lapse of time (under conditions, therefore, where the air must be saturated with moisture) seems to be positive proof against the view that these coronas owe their origin to undersaturation. The corona immediately following (second exhaustion) is always a superior corona. One may note that if extremely fine nuclei (colloidal molecules) pass the filter, a time loss like the present would accompany their decay.

20. Effect of pressure difference on exhaustion.—The reason for irregular results in tables 13, 14, and 15 is now apparent, for in these experiments the tendency to periodicity was not yet understood. Nor can it in any case be effectually combatted. After the fog chamber has been cleared of foreign nuclei, which occurs at a pressure difference above 20 cm. of mercury and at about the same volume expansion in both chambers, the effect of further increasing the pressure difference, δp, is an exceedingly rapid increase of the apertures of coronas. The first coronas after the air is made dust-free are usually particularly large. Though this looks like a foreign effect, it is probably due to periodicity.

Very soon, however, the effect of δp ceases to increase the apertures. All the *s*-curves either pass through a maximum or reach a limiting asymptote, as is particularly marked in case of table 15 (figs. 20 and 21). The fog limit lies a little lower in case of the large chamber (wood, $v/V=0.13$) than in the case of the small chamber (glass, $v/V=0.063$), an anomalous result, since the latter condensation must be the swifter. There does not seem to be any adequate effect for the relative suddenness of condensation in the two cases. The last parts of table 13 contain examples in which, with the same apparatus and apparently under identical conditions (dew on one side of the glass), a steady and thereafter an oscillating aperture is encountered. The last series gives an instance of oscillations which vanish when the water in the fog chamber is shaken from side to side.

TABLE 13.—Effect of pressure difference. Long condensation chamber. $v=55\times 12\times 20=13,200$ cm.³, for fog chamber; $V=106,000$ cm.³, for vacuum chamber $v/V=\frac{13,200}{106,000}=0.125$. Instantaneous valve. Goniometer 85 cm. from fog chamber.

δp.	s.	$N\times 10^{-3}$.	δp.	s.	$N\times 10^{-3}$.
Outgoing.			Returning.		
19.6	0.0	0.0	33.0	2.0	5.9
24.2	1.8	3.7	29.2	2.9	19.8
24.2	1.8	3.7	25.8	1.5	3.1
28.3	3.0	21.5	22.7	.9	1.9
32.7	3.0	25.9	20.0	.0	.0
37.4	3.1	33.7			

TABLE 14.—Cylindrical condensation chamber. $v/V=0.06$. Instantaneous valve. Goniometer 85 cm. from fog chamber.

δp.	s.	$N\times 10^{-3}$.	δp.	s.	$N\times 10^{-3}$.
Outgoing.			Outgoing.		
18.8	0.0	0	35.1	2.5	16
20.4	0.0	0	42.6	2.6	24
20.7	0.0	0	52.2	3.5	102
25.6	*4.1	84			

* Initial excess.

TABLE 15.—Cyclic variation of pressure difference. Cylindrical condensation chamber. $v/V = 0.06$. Plug valve (1-inch bore). Goniometer 85 cm. from fog chamber.

δp.	s.	$N \times 10^{-3}$.	δp.	s.	$N \times 10^{-3}$.
Outgoing.			Returning.		
15.2	0.0	0	48.9	4.1	136
18.5	0.0	0	46.3	3.6	77
20.9	(?)	0	43.3	3.7	72
20.1	0.0	0	40.8	2.9	32
20.2	(?)	0	38.4	4.5	110
26.2	*4.0	46	35.7	3.1	31
26.2	2.4	9.6	33.5	5.0	126
26.2	2.5	11	30.8	3.2	29
36.6	3.2	36	28.9	3.4	33
36.6	3.2	36	27.0	1.9	4.9
43.7	4.2	113	24.7	1.8	3.7
43.7	4.3	123	23.1	1.3	2.3
51.4	3.7	112	21.8	? 0.0	0
			20.6	0.0	0
			19.5	0.0	0

* Initial excess.

TABLE 16.—Effect of pressure difference. Cylindrical condensation chamber. Instantaneous valve. Eye at goniometer, 85 cm. from fog chamber. N reduced to normal atmospheric pressure.

δp.	s.	$N \times 10^{-3}$.	δp.	s.	$N \times 10^{-3}$.
20.1	0.0	0	34.7	5.0	132
20.5	0.0	0	34.9	2.7	20
20.7	0.0	0	34.8	5.1	140
23.3	3.0	18	34.8	2.6	18
			34.8	5.1	140
26.1	2.2	7	34.8	2.7	20
26.3	4.0	46	43.6	*5.4	237
26.2	2.6	12	43.5	5.1	202
26.2	4.1	50	43.5	5.8	279
26.2	2.2	7	43.5	3.0	41
26.2	4.3	58			
26.2	2.6	12			

* Valve injured.

In table 16 the occurrence of marked periodicity gives rise to two distinct s-curves, both of which soon approach an asymptote (figs. 22, 23). In the last group of observations the alternations are not regular (leakage of valve), but the extremes are indicated. Differing from this, the results of table 17 in the outgoing series of apertures (δp, increasing) are remarkably free from periodicity and show a tendency to pass through a maximum. In the return series much fresh air was drawn through the filter into the fog chamber and thence into the vacuum chamber. It is noteworthy that very large coronas are then met with on first exhaustion, a result which may bear on the explanation of periodicity.

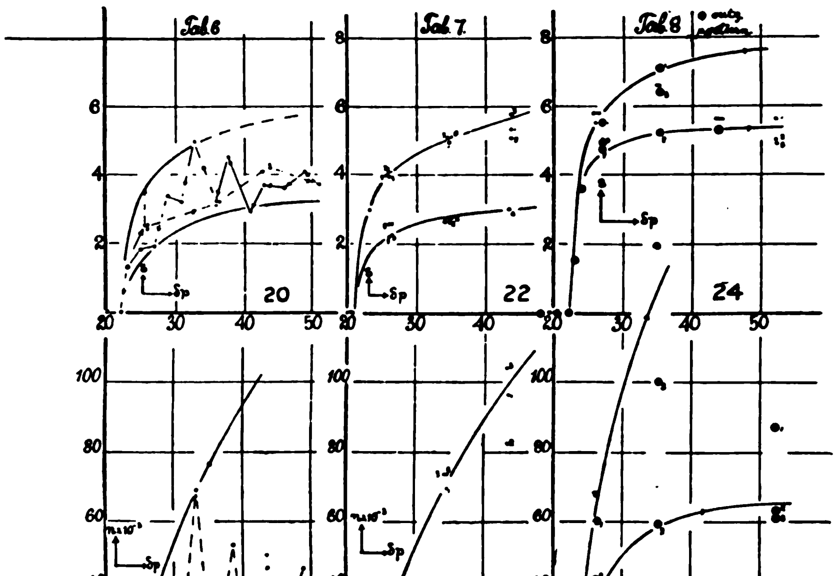
In table 17 (figs. 24, 25) the goniometer was moved close to the fog chamber to insure clearer vision. The chart (figs. 20–25) on page 26 shows, n, the number of nuclei per cubic centimeter of the expanded air; in the tables the number, N, reduced to air at normal pressure and temperature is usually given.

TABLE 17.—Cyclic variation of pressure difference. Cylindrical fog chamber. Plug valve. Eye at goniometer, 50 cm. from axis of cylinder.

δp.	s.	$N \times 10^{-3}$.	δp.	s.	$N \times 10^{-3}$.
Outgoing.			Returning.		
19.5	0.0	0	43.8	5.3	171
26.2	5.8	105			
26.5	5.8	106	35.3	*7.1	267
26.2	5.5	94	35.3	5.2	113
26.2	5.8	105	35.3	6.4	194
35.4	6.6	211	26.5	*5.5	94
35.0	6.6	209	26.3	4.7	59
			26.3	4.9	67
44.2	5.6	207			
43.8	5.6	203	24.0	3.6	24
43.8	5.6	203	22.8	1.5	2.5
			22.2	0.0	0
52.3	5.6	297	20.5	0.0	0
52.4	5.0	215	18.0	0.0	0
52.4	4.9	209			

* Nuclei probably enter from large influx of air through filter. Therefore next coronas are small from undersaturation and periodicity. These fine nuclei get gradually out of reach as δp decreases.

21. Remarks on the tables.—It will conduce to clearness to take the last tables showing the increase of apertures, s, with the increase of presure difference, δp, first in order. All the s-curves, figures 20–25, either pass through a maximum or reach an asymptote. If the exhaustion is insufficient the groups of smaller nuclei will escape precipitation and the coronas be relatively small. This will also occur if relatively large nuclei are accidentally present. After all nuclei, large and small, are caught, higher sudden exhaustion can no longer increase the apertures. More water is instantaneously precipitated per cubic centimeter. Nevertheless this counter-effect, if it is such, will also vanish with increasing pressure differences, because of the accentuated rapidity of thermal radiation. The adiabatic method ceases to be effective. Finally the necessity of producing sudden cooling simultaneously with extreme dilatation is a complication; for in view of the relative slowness of diffusion, it will eventually be impossible to keep the instantaneously dilated water vapor saturated without arresting the growth of the fog particles. Above $\delta p = 40$ cm. the effect of sudden exhaustion might actually dry the air, seeing that the density of vapor is instantly reduced more than one-half. It is thus conceivable that even slight differences of supersaturation at the outset may show themselves effectively at these high exhaustions. In table 16, however, the nucleation N (reduced to normal pressure) increases almost linearly with the pressure difference even at the highest exhaustions. The evaporation of the smaller fog particles is probably an essential part of the whole phenomenon.



FIGS. 20–25.—Change of apertures (s) of coronas and number of efficient nuclei (n) varying with different pressure differences (δp) for the cases of superior and inferior coronas. Dust-free air.

Table 6, referred to in fig. 20, will be found as table 15, p. 24.
Table 7, referred to in fig. 22, will be found as table 16, p. 24.
Table 8, referred to in fig. 24, will be found as table 17, p. 25.

22. Blurred coronas.—The occurrence of an abundance of rain with all the coronas, as well as the blurred appearance of the coronas themselves, shows that gradation of particles is a characteristic feature with all these condensations. The following results for periodicity apparently indicate the presence of a group of markedly large particles in the amount of about one-eighth or more of the total number of nuclei.

23. Time effect.—In the lapse of time exceeding even half an hour the aperture of all coronas usually diminishes in marked degree. Above the fog limit, however, the coronas do not vanish as the result of repeated exhaustion, *i. e.*, the air can not be freed from nuclei by being stored in a closed vessel (fig. 19). What is particularly remarkable is the rapidity with which nuclei precipitated by condensation are again replaced. Whether these come through the filter in quasi-gaseous form (remembering that they must be much smaller than ions), or whether they are spontaneously produced in the imprisoned air, is yet to be decided. In every case something has to be explained away. If the nuclei came through the filter, for instance, they would not come through periodically.

24. Oscillations at variable pressure differences.—With increasing pressure differences, δp, the superior and the inferior apertures each lie on distinct curves, both of which rise rapidly at first, are then rapidly retarded, and tend to reach distinct maxima (figs. 20–25). The limiting ratio of apertures is liable to be nearly one-half. If, however, the pressure difference is carried far enough, both s-curves sometimes change character by decreasing and increasing, respectively, eventually to reach a common value. If, then, pressure difference is in turn reduced from these final values, the oscillation of s is usually absent and a mean nucleation appears at all subsequent (decreasing) pressure differences.

25. Nucleations at varying pressure differences.—The increase of nucleation, n, with the pressure difference, δp, is difficult to interpret, since the inferior and superior values are so much more widely and irregularly distributed (figs. 21, 23, 25). The n-curves usually show two limiting rates of increase of n with δp, respectively very large and very small. This is particularly well brought out in the data of table 16 and figure 23, where both loci are nearly straight even above $\delta p=40$ cm. They become more so if the nucleation is reduced to normal pressure, as shown under N. Using this suggestion the data of table 13 (wooden fog chamber) are largely referable to inferior coronas. With one exception, this is also the case in table 14 for the glass cylinder, while in table 15 there is an irregular distribution of observations between both classes of curves. In table 17 inferior coronas are absent, and those observed present an accentuated case of superior corona. The series fails to detect the large coronas after $\delta p=35$ cm., so well brought out in table 16. One may note the different valves used.

26. Fog limits.—An interesting feature of these results are the fog limits or pressure differences at which condensation in dust-free air just commences. In spite of the different sizes of apparatus and valves used, the fog limits are about the same, viz, in tables 13, 14, 15, 16, and 17.

Table.	δp—	Apparatus.	Valve.
13	22-23 cm.	Wood, $v/V=.13$	Plug.
14	21.5	Glass, $v/V=.06$	Clapper.
15	22-23	" " "	Plug.
16	21-23	" " "	Clapper.
17	22-23	" " "	Plug.

These results are surprising, inasmuch as the effect of the volume ratio of fog and vacuum chambers and the valve effect would naturally be looked to as productive of larger differences. With other apparatus (Chapter I) the data were:

δp—	Apparatus.	Valve.
22	Wood, $v/V=.7$	Plug.
20	" " .7	Clapper.

Thus the supreme importance of mere rate of exhaustion may well be called in question until more definite results appear; for with so large a difference of volume ratio, valve obstruction, etc., the essential features should appear more clearly. It is possible that nuclei of extreme fineness (colloidal molecules) may pass through the filter. In such a case these would capture most of the water vapor, reducing the size of coronas by prohibiting condensation on still smaller colloidal molecules. Therefore, if the filter is entirely dispensed with and a closed vessel used, larger coronas may appear at smaller pressure differences.

27. Oscillations at fixed pressure differences.—Effectively the case of oscillation is one in which the large, sparsely distributed fog particles emit more nuclei and the very abundant small fog particles fewer nuclei, *i. e.*, the phenomena may be looked upon as though the nuclei were generated during the growth of the fog particles. This plausible result, however, is not to be maintained; for the emission would have to be as the growth of surface—in other words, as the volume—and the number of particles varies inversely as their volume. A counter supposition may be hazarded to the effect that the fog particles of large coronas absorb more nuclei because of their abundance than the fog particles of small coronas. But the period of suspension of particles is too short a period to be of moment.

If negative ions are more active as condensation nuclei than positive ions, the results observed may be tentatively grouped in accordance with the following scheme:

$$\begin{array}{cccccccc}
1 & & & 2 & 3 & & & 4 \\
(+) & \longleftarrow & \longrightarrow & (-) & (+) & \longleftarrow & \longrightarrow & (-) \\
(-) & & & (+) & (-) & & & (+) \\
\downarrow & & & \downarrow & \downarrow & & & \downarrow
\end{array}$$

Let the ions be originally neutral as a whole, and suppose, as in case 1, that the negative ions are first precipitated. In the interval between this and the next exhaustion fresh ions are generated or taken in through the filter, as shown in case 2. If these negative ions partially neutralize the positive ions left over in case 1, the second precipitation takes place on the positive ions. Thereafter, case 3, the first is repeated, etc. But if the coronas are taken as a measure of the number of particles, the number of effective nuclei must be eight times larger in the first case than in the second, whereas the ions should be present in equal numbers. Hence there is serious objection to this hypothesis at the outset, quite apart from the absolute numbers in question, which are enormously too large to be referred to ions.

28. Undersaturation.—Some mechanism of this kind is nevertheless probable, and it will suffice if the undersaturation produced by the precipitation of fog particles is not rapidly made up by diffusion and convection, or, even better, if water nuclei are produced by evaporation of fog particles. Of the above hypotheses that of undersaturation has broad bearings and accounts qualitatively for most of the phenomena, as will presently be pointed out in detail. True, the large coronas must be supposed to carry down more moisture than the small coronas, but the difference need not be great. The hypothesis encounters a serious obstacle, inasmuch as the coronas obtained from saturated air which has been imprisoned for long intervals of time (section 8) are usually an extremely small type of inferior corona, whereas they should be large superior coronas. Long intervals of waiting between exhaustions bring out not a superior corona but at best one of intermediate size. Another precarious feature is suggested by computating the rate at which saturation should be established in the most unfavorable case of the middle air layer, between the wet top and bottom of the fog chamber, for diffusion alone.

In fact, if diffusion takes place from the wet top and bottom of the rectangular trough of height a into a partially saturated atmosphere of initial vapor pressure p_0, then at any time t, at the middle plate $x=a/2$

$$p=1+\frac{4(p_0-1)}{\pi}\left(\sin\frac{\pi}{2}\epsilon^{-(\pi/a)^2kt}+\frac{1}{3}\sin\frac{3\pi}{2}\epsilon^{-(3\pi/a)^2kt}+\text{etc.}\right)$$

where $dp/dt=k\,(d^2p/dx^2)$. Hence if $a=11$ cm., as in the largest trough (wood), and if $k=0.23$, the following values obtain:

$t=$	$p_0=0$, $p=$	$p_0=1/3$, $p=$	$p_0=2/3$, $p=$
30	.28	.52	.76
60	.59	.72	.86
120	.87	.91	.96
180	.96	.97	.99

In the above tables a was usually less than 10 cm. (glass fog chamber), making the condition correspondingly favorable.

Hence by diffusion alone there should be saturation after 2 to 3 minutes even at the most distant (middle, $x=a/2$) plane, to within a few per cent, for the central layer is probably always more than half saturated at the outset. In addition to diffusion, however, there is marked convection due to the lightness of water vapor. At the same time there is no evidence that the more numerous but small drops of the superior coronas carry down a sufficient excess of water; nor are the coronas, though blurred, otherwise distorted, as they would be for a definite diffusion gradient.

29. Undersaturation, continued.—Assuming, however, that undersaturation* does occur and is oscillatory as the result of successive

* It will be shown below, Chapter VI, sections 97, 98, that the probable cause of periodicity is not undersaturation but the production of water nuclei by the evaporation of the small fog particles. The analysis of the phenomena given in section 14 applies, however, with obvious changes, to both cases, and has therefore been retained in the text.

larger and smaller precipitations, the cases may be interpreted in succession as follows:

a. The superior coronas carry down more moisture and should be followed by even larger coronas, and vice versa; but after the fog particles producing the superior coronas are precipitated, the supersaturation possible for the given pressure applied no longer catches the small nuclei. Hence the inferior coronas appear in succession. Hence, also, apart from what may be time errors in opening the stopcock, very large pressure differences tend to wipe out the oscillation, as all nuclei are caught.

b. The ratio of 1:2 for coronal apertures and of 1:8 for the volumes of fog particles seems out of keeping with the slight differences of supersaturation instanced in section 28; but this is again a question of catching the group of smaller nuclei.

c. The phenomenon is much too definite an oscillation of aperture between s and $2s$ (nearly) to be referable to an irregular cause like deficient supersaturation; but the two types of nuclei admit of a wide range of saturation, as long as there is a correspondingly wide difference in the sizes of nuclei.

d. A series of minor observation are favorable to the hypothesis of residual undersaturation; as, for instance, the eventual coalescence of the aperture curves of the superior and the inferior coronas; the dew effect; the fog effect and shaking; the fact that very small inferior coronas are followed (*cæt. par.*) by large superior coronas, while the latter are followed by large inferior coronas, etc.

e. Finally, while superior coronas are followed by inferior coronas, and vice versa, mean coronas follow each other.

30. Nucleation.—The values of the nucleation (number of nuclei per cubic centimeter) of the inferior and the superior coronas naturally present a more striking contrast, since the third power of aperture is involved. Otherwise but few new results are to be inferred from them. If the long series of table 10, part II, be taken, which contains the data of twenty successive alternations, the average inferior nucleations are 11,800, and the average superior nucleations 94,000, supposing, of course, that the precipitated water is the same in both cases and that it is all condensed on the available nuclei. In other words, if the two cases are identical, the superior coronas correspond to a number of nuclei 8 times greater (frequently larger than this in the other observations) than the inferior coronas. As this explanation is the more probable, it follows that the nuclei can not be regarded as positive and negative ions. They are rather the groups of large and small nuclei seen throughout the condensations in connection with the rain and blurred coronas. Apart from this, the numbers obtained throughout are quite out of keeping with any similarly observed ionizations. If, however, free electrons appear only at the destruction or at the origin of nuclei, the association of few ions with many nuclei at any time subsequent to their origin is well accounted for, as already suggested in the earlier paper. It is only while the nuclei are being produced that the ionization and the nucleation must be of the same order; for the latter persists while the former vanishes at once. Finally the following results are implied, at least for the physical structure of air saturated with water vapor:

Air (dust-free) is inseparably intermixed with large and small nuclei, whose number (to be reckoned in millions per cubic centimeter) rapidly increases as the order of molecular size is approached. There seems to be no objection to looking upon these nuclei as a kind of colloidal (air) molecule, particularly as such molecules are frequently producible by the means (Bredig) which produce nuclei. If a large number of free atoms is suddenly introduced into any region (and this is probably what the radiation of the above kind virtually does) the result is not merely a production of typical molecules but of a large concomitant of graded nuclei.

Practically any given nuclear status of air is a counterpart of the intensity of the ionization of the medium in which the nucleation originated, to the effect that the superior limit of size of the nuclei and their number increase with the ionization. But there is no case of ionization free from nucleation, be the exciting cause a mere radiation as above, or ignition, combustion (including the low-temperature cases like phosphorus), or high potential discharge, or violent comminution as in the case of water nuclei.

EXPERIMENTS WITH DUST-FREE AIR ENERGIZED BY RADIUM.

31. Effect of radium in hermetically sealed glass tubes.—A modification was now introduced by inserting a small vial of thin glass (walls 0.04 cm.) containing about 0.01 gram of impure radium (strength 10,000×) in the B end of the rectangular apparatus, Chapter I, figure 1. For clearer vision, the eye at the goniometer was placed at about 35 cm. from the nearer glass plate of the fog chamber, and the apertures so obtained, larger than the customary values by about 10 per cent, appropriately corrected. The data of most of the tables are reproduced in the chart containing figures 26–32.

The filtered air was first examined without interference, as in table 18, in the complete absence of radium, and a similar test precedes all the subsequent observations. The results for air are without periodicity here (figs. 27, 28), and show a high fog limit at about $\delta p = 24$ cm., the coronas at $\delta p = 24.7$ being just appreciable. The reason for the raised fog limit (air freer from dust) is not apparent; but the volume ratio of fog and vacuum chambers is here $\delta p = 0.13$.

The immediate effect of introducing radium is seen in the second part of the table, at first without periodicity, and the fog limit is at once reduced to $\delta p = 19$ cm. (figs. 27, 28).

TABLE 18.—Effect of radium immediately after insertion. Long condensation chamber. $v = 11{,}000$ cm.^{3}; $v/V = 0.13$. Temperature, 26° C. Plug valve. Goniometer close to apparatus.

Filtered air without radium.

δp.	s.	$N \times 10^{-3}$
20.6	0.0	0
21.5	0.0	0
23.4	0.0	0
23.2	0.0	0
24.7	1.5	2.7
24.7	1.3	2.4
29.5	3.2	20
29.6	3.5	27
29.8	3.4	25
33.1	3.5	32
33.0	3.4	27

Radium tube inserted.

δp.	s.	$N \times 10^{-3}$
29.5	4.8	75
26.9	3.9	33
24.4	3.6	24
22.0	2.5	7
20.1	1.3	2
18.0	0.0	0
18.0	0.0	0
After 75 min.		
18.0	0.0	0
20.1	1.7	2
21.6	3.8	25
23.3	2.6	8
24.8	5.2	73
24.8	3.0	13
24.8	5.3	76
24.8	3.0	13
After 135 min.		
24.8	6.0	111

δp.	s.	$N \times 10^{-3}$
*24.8	6.0	74
24.8	3.1	9.6
24.8	5.3	70
24.8	2.8	6.9
24.8	5.5	58
24.8	3.0	8.7
24.8	4.8	51
24.8	2.3	3.5
24.8	5.4	55
24.8	2.8	6.8
After about 90 min.		
24.8	5.4	55
24.8	2.4	4.3
After 18 hours.		
24.8	* 6.2 2.7	†100 6.8

* Periodicity. † $N = 150{,}000$; ratio $1.5 = N/n$.

Nucleation, 75 minutes after the first observations, has much increased (*cæt. par.*); but direct comparison is not possible, because the latter data are now distinctly periodic, and an upper and a lower curve of apertures has appeared, without appreciably displacing the fog limit. After further 135 minutes, the upper limit has probably reached a stationary value (figs. 27, 28).

In the last part of the table the periodicity of aperture, s, for air in the presence of radium, is specially investigated for $\delta p = 24.8$ cm. Exceptionally high superior values of s are again followed by exceptionally high inferior values (fig. 26), while exceptionally low inferior values are followed by high superior values. The oscillatory curves usually rise from great depth to great height. The s-curves sometimes show a tendency to double inflection after $\delta p = 24$ cm. is exceeded, referable, it would seem, to the normal air ions added to the radium ions.

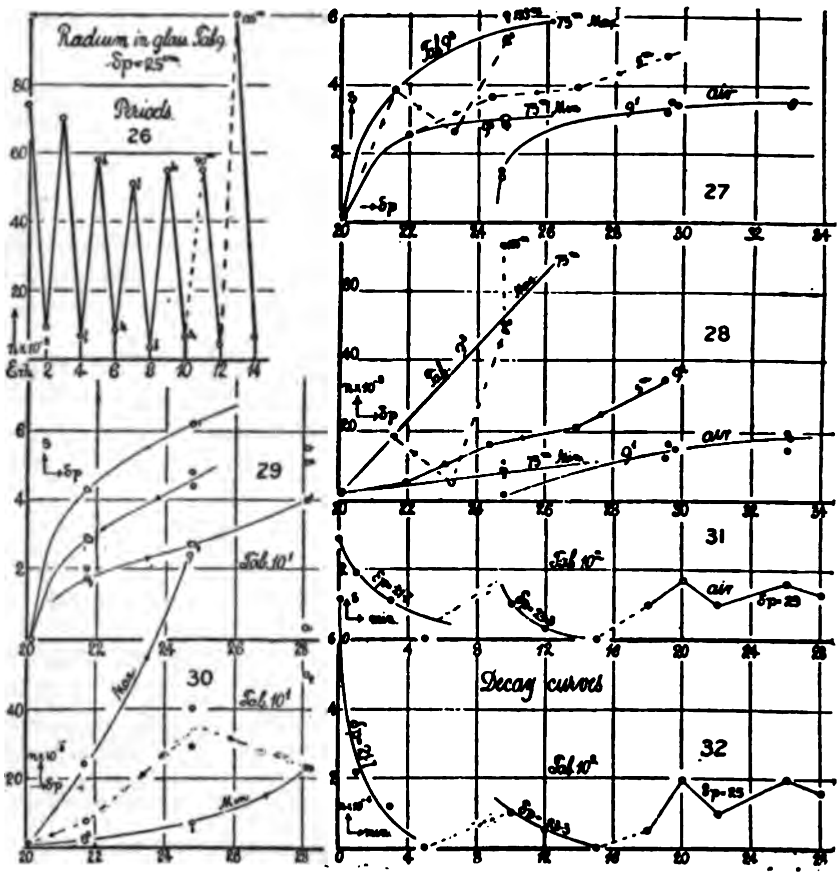


FIG. 26.—Number of efficient nuclei (n) obtained in successive exhaustions of dust-free air energized by radium. Periodicity.

FIGS. 27–30.—Change of apertures (s) of coronas and nucleations (n) varying with the pressure differences (δp) in cases of dust-free air energized or not by radium (in sealed glass). Arrows show the march of the observations. Periodicity is apparent.

FIGS. 31–32.—Decay of nuclei produced by radium after removal of tube from fog chamber. Radium in glass tube.

Table 9, referred to in figs. 26, 27, and 28, will be found as table 18, p. 33.
Table 10, referred to in figs. 29, 30, 31, and 32, will be found as table 19, p. 35.

In table 19 the same effects are studied after the radium was in the apparatus for over 24 hours. The data in the outgoing series (δp increasing) are distinctly periodic, until the highest value $\delta p = 28.1$ cm. is reached, which seems to wipe out the periodicity for the returning series (figs. 29, 30). Curiously enough, the fog limit has apparently risen, being now $\delta p = 20$ cm., instead of 19, as in table 18. If all results be compared at about $\delta p = 25$ for mean values of s, they show for—

Air (no exposure),	$s = 1.4$		$n \times 10^{-3} = 1.7$
Radium, short exposure,	3.6	(no periods)	16
exposure, 2 hours,	4.1	(periods, $s = 30 - 52$)	23
exposure, 24 hours,	4.5	(periods, $27 - 62$)	32
Air (20 minutes after removing radium),	1.4		1.7

Long exposure to radium has increased the amplitude of the variation of aperture, s. The limiting maxima for high values of δp in the case of radium are in excess of the corresponding values for air.

TABLE 19.—Effect of radium left in apparatus 24 hours (23° C.) and thereafter removed.

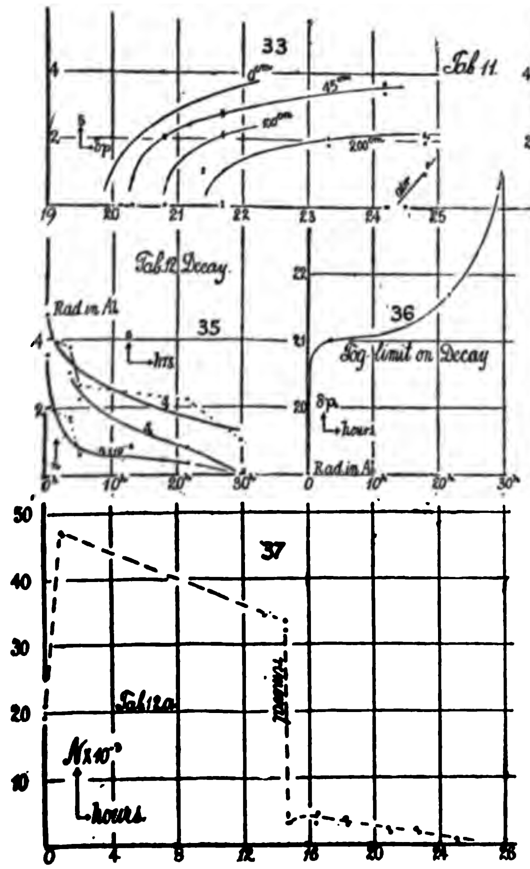
Radium present.			Radium removed.			
δp.	s.	$N \times 10^{-3}$.	Time.	δp.	s.	$N \times 10^{-3}$.
			Min.			
16.0	0.0	0	0	......	Removed.	...
18.0	0.0	0	1	21.7	1.9	3
20.1	Just seen.	0	3	21.7	1.1	2
*21.7	4.3	34	5	21.7	0.0	0
21.7	1.7	2	10	23.3	1.0	1
24.8	6.2	116	12	23.3	r'	r'
24.8	2.7	10	15	25.0	0.0	0
†28.1	5.5	101	17	24.8	*r'	r'
28.1	5.1	81	20	24.8	1.7	3
28.1	4.0	37	22	24.8	r'	r'
‡24.8	4.4	43	25	24.8	1.6	3
24.8	4.8	60	28	24.8	1.3	2
21.7	2.0	3				
21.7	2.9	10				
21.7	2.9	10				

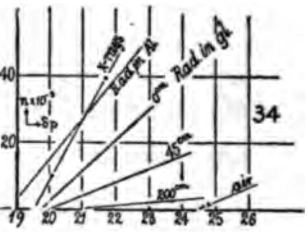
* Periodicity even in the absence of coronas. † Periodicity ceases. ‡ Returning.

32. Remarks on the tables.—The inference has already been drawn that the number of nuclei as well as their size varies as the ionization per cubic centimeter. The fog limit is reduced by the presence of weak radium in sealed thin glass tubes within the chamber, from $\delta p = 24$ to 19 cm., observations which may be made pretty sharply. This implies (quite apart from number) that the nuclei in the presence of radium are larger, as they are the offspring of a more highly ionized field than exists in nonenergized identically filtered air. But apart from the fog limit, the number of nuclei large enough to fall within the scope of any given δp is correspondingly increased.

The fog limit of filtered air after the radium is withdrawn soon regains its original value; but some definite time (say 15 minutes) is necessary even here. It does not seem to vary appreciably with the time of exposure. (See figs. 31, 32.)

As the radium of low power (10,000×) is inclosed in glass 0.04 cm. thick, it is probable that β and γ rays are chiefly responsible for the nucleation. Hence it appears that nuclei are produced by sufficiently swift moving corpuscles as well as by the X-rays, an important result bearing on an inquiry suggested above. This will be further substantiated in the next chapter in favor of the gamma rays.





FIGS. 33–34.—Apertures of coronas (s) and nucleations (n) varying with the pressure differences (δp), for the case of dust-free air energized by radium acting from different distances.

FIGS. 35–37.—Decay curves found after the removal of the radium from the fog chamber.

Table 11, referred to in fig. 33, will be found as table 20, p. 37.

Table 12, referred to in fig. 35, will be found as table 21, p. 38.

Table 12a, referred to in fig. 37, will be found as table 22, p. 40.

33. Data for nucleation.—The results for nucleation in case of a dust-free atmosphere energized by radium (10,000×) contained in a hermetically sealed glass tube are clearest in the third part of table 18, where nearly straight n-curves for inferior and superior coronas may be made out (fig. 28). Part 2, containing data obtained shortly after the radium tube was introduced, is not easily interpreted, but the action of radium is obviously weaker. In most cases there is marked periodicity, and part 4 of the table proves that the nucleation is over 9 times greater for the superior than for the inferior coronas. After an exposure of 18 hours, the nucleation of the superior coronas is fully 20 times greater.

In table 19 the nucleations of the superior and the inferior coronas are particularly striking at $\delta p = 25.8$, and the ratio is actually 11 (fig. 30). Thereafter periodicity vanishes with falling nucleations and the return n-curve is along an average path. If periods were due to the gradual growth of nuclei, supposing that the time between *two* successive exhaustions is needed to bring the nuclei within the scope of the given pressure difference, there would be no reason for the relatively unbroken return. Oscillation appears to be wiped out by high pressure differences as well as in a march of decreasing values.

TABLE 20.—Radium at different distances from line of sight. Interval between exhaustions usually 2 minutes.

Distance.	δp.	s.	$N \times 10^{-3}$.	Distance.	δp.	s.	$N \times 10^{-3}$.
∞	24.2	0.0	0	∞	24.5	0.0	0
	24.2	0.0	0		24.8	1.0	2
	24.8	1.2	2				
	24.8	1.3	2				
				200	21.7	†2.3	4
45	24.2	3.7	27		21.7	1.6	2
	24.2	3.4	19		21.7	0.0	0
	21.7	2.8	9		21.7	0.0	0
	21.7	2.7	9		21.7	2.0	3
	20.1	0.0	0		21.7	1.8	3
	20.3	0.0	0				
45	20.8	2.1	4		21.4	1.1	2
	20.8	2.0	3		21.4	1.0	2
	20.1	0.0	0				
	20.3	0.8	1				
					23.3	1.8	3
100	21.7	*2.2	4		23.3	2.0	3
	21.7	1.0	2				
	21.7	2.2	4				
					24.8	1.9	4
	21.7	*(2.5)	7				
					24.8	2.1	4
	21.7	1.6	2				
	21.7	2.1	4				
	20.8	0.0	0		24.8	†2.2	5
	20.8	0.8	8		24.8	2.1	4

* Periods?. † After 40 minutes' exposure.

34. Fog limits raised by weaker ionization.—The view taken in this paper that the size of the nucleus increases with the intensity of the ionization may be tested by removing the radium from the apparatus and allowing it to act from increasing distances (figs. 33, 34). This is the case in table 20, where observations to determine the fog limit are given when the radium is placed at 45 cm., 100 cm., 200 cm., respectively, from the end of the fog chamber, or, better, from the line of sight. Whenever radium is not too far from the apparatus the change of fog limit may be made out sharply as—

Distance,	0	45	100	200	∞	cm.,
$\delta p =$	19	20.2	20.8	21.5	24.5	cm.,

showing that the nuclei increase in size with the intensity of the ionization. These and the following data are mapped out in figure 34 of the chart, n instead of N (reduced to normal pressure) being usually inserted. In case of long distances (200 cm.) the results are apt to be irregular. On removing the radium to a great distance the fog limit of air is soon restored, and it will be seen that all observations are introduced by test experiments with dust-free air.

TABLE 21.—Coronas for a given pressure difference and fog limits after removal of radium (0.01 gram, 10,000×, in hermetically sealed aluminum tube) from inside of fog chamber.

Time.	δp.	s_1.	s_2.	Fog limit.	$n_1 \times 10^{-3}$	n_2
h.						
0	*21.7	4.8		19	36	
0	*19.0	1.2			2.1	
0.1	†21.7	4.0			20	
0.3	21.7	4.0			20	
0.7	21.7	4.0			20	
3.5	‡21.7	3.7	3.0	21	17	8.0
	20.0	0.0			0	
5.0	‡21.7	2.6	2.2		5.6	4.0
21.5	‡21.7	2.2	0.8	22	3.0	0.8
29.5	21.7	1.0	0.0	23	1.1	0.0
	24.7	1.2			1.4	

* Radium present. † Radium removed. ‡ Successive exhaustions.

35. Nucleation.—An important interpretation of the preceding results is obtained by mapping out the nucleations, n, in relation to the corresponding pressure differences, δp (fig. 34). The slope of these curves falls off rapidly for radium at 0, 45, 200 cm. from the fog chamber, while the fog limit rises. In other words, the initial slope of the n-curves is steeper as the fog limit is lower. Thus per increment of δp of 1 cm. of mercury, above the fog limit of the ionized medium, and below the fog limit of nonenergized dust-free air, there will be found in succession for radium in—

Sealed aluminum tube within fog chamber,	δn—12,000
Sealed glass tube within fog chamber,	6,000
Sealed glass tube, outside, 45 cm. from fog chamber,	3,500
Sealed glass tube, outside, 200 cm. from fog chamber,	1,000
Dust-free air (above fog limit, radium at infinity),	10,000

Hence the gradation is effectively more even, finer, *i. e.*, with fewer gaps, as the fog limit is low and the maximum size of nucleus larger, while for sparse distribution the steps from any nucleus to the next in order of size are relatively large. For a different medium, dust-free air, for instance, as given in the summary, or figure 34, the gradation is characteristically different. Later experiments (Chapter III) make it probable that the curves for dust-free air, not energized, and dust-free air energized by radium and X-rays, make a continuous series.

36. Radium in sealed aluminum tube.—The identical sample of radium (0.01 gram, 10,000×) was now removed by cutting the glass tube, put into an aluminum tube (walls about 0.1 mm. thick), and again hermetically sealed. This tube was introduced into the inside of the fog chamber, kept in place 15 minutes or more, and then removed to an infinite distance. The results obtained are different from the preceding case of the same radium in the thin glass tube; for whereas the fog limit of dust-free air was regained 15 minutes after the removal of the glass tube (figs. 31 and 32), it took at least 30 hours to restore the same fog limit after the removal of the aluminum tube. Table 21 shows the results, where s_1 and s_2 are apertures obtained in successive exhaustions about 2 minutes apart, dust-free air being added to the fog chamber in the interval (fig. 35).

The successive fog limits for radium sealed in the thin aluminum tube are, therefore, in centimeters of mercury (fig. 36),

Radium in place,	$\delta p = 19$
Radium tube removed:	
Fog limit 3½ hours later	21
" 21 "	22
" 30 "	23

provided time is allowed for the excited activity within the chamber to saturate the air with nuclei (cases s_1). When such time is not allowed as in the succeeding exhaustions (cases s_2), the fog limit of dust-free air is practically regained in 30 hours. Something like an emanation seems here to escape from the aluminum tube rapidly and from the glass tube slowly, in spite of their thickness, relatively speaking, and induces radio-activity at the inner walls of the fog chamber; or possibly this induced activity is a kind of phosphorescence produced by the impinging β and γ rays. It seems probable that the life of the excited activity may be prolonged at pleasure within limits, by gradually decreasing the walls of the aluminum tube hermetically sealing the radium excitor.

The loss of the activity shown by the rise of the fog limits in the lapse of time is naturally of an exponential character (fig. 36). It rises quickly after the removal of the radium from $\delta p = 19$ to about

$\delta p=21$, after which the true exponential march due to the excited activity begins. It would be better to state these data in terms of the number of nuclei produced after indefinite exposure (nuclear saturation), the number to be found by a given sufficiently high pressure difference below the fog limit of dust-free air. But the observations of table 21 are scarcely advanced enough for this purpose. In fact, the irregularity of size of the coronas s_1 obtained at the given pressure-difference, $\delta p=21.7$, is worthy of remark. The curves obtained in the second exhaustion (s_2), whereas but a few minutes of exposure of the air to the excited activity are in question, are much smoother. The n-curves do not suggest any further comment.

The above experiments on radio-activity, induced by radium contained in a closed aluminum tube placed within the fog chamber, having been made soon after the tube was filled and sealed, it was thought necessary to repeat the work two months later with the same tube. As a safeguard this was additionally sealed at the ground joint (screw plug) with resinous cement. Data so obtained with the wood fog chamber were curiously irregular, showing periodicity occurring in triads. Large coronas appeared after long waiting (15 hours), and it is therefore probable that there was some slight leak whereby air nuclei entered the fog chamber and captured much of the precipitated water. In contrast with these suspicious results, the data for decay curves were consistent, showing an increase of nucleation within about 20 to 30 minutes subsequent to removal, after which a gradual decay occurred to about one-half in 6 hours. But the data as a whole were discarded.

The experiments were now repeated in the glass fog chamber, which had been specially tested for freedom from leaks. The exhaustions made below the fog limit for dust-free air are shown in table 22 and figure 37.

TABLE 22.—Radium in fog chamber. Sealed aluminum tube. $\delta p=25$ cm. Successive exhaustions, 1^m–2^m apart.

Exh. No.	s.	$N\times 10^{-3}$	Exh. No.	s.	$N\times 10^{-3}$	Exh. No.	s.	$N\times 10^{-3}$
1	4.5	48.0	9	4.4	44.0	16	2.3	5.4
2	2.6	9.2	10	2.2	5.0	17	2.5	8.0
3	1.0	1.8	11	.0	.0	18	2.7	10.4
4	*5.0	67.0	12	3.4	20.4	19	4.0	32.4
5	2.7	10.4	13	3.3	18.6	20	†5.2	74.4
6	1.0	1.8	14	*3.8	30.0	21	3.7	28.6
7	4.4	44.0	15	*2.0	3.8	22	3.7	27.6
8	2.2	5.0						

* Renewed after waiting 5 minutes or more. † Next day.

The new data are, in fact, quite different from the old. After introducing the sealed radium tube the nucleation rises rapidly to a maximum, falling off, however, to a mean value in 14 hours. On removing the radium tube from the chamber, the nucleation falls off at once to about 10 per cent of its original value. This appreciably increases a little at first, but vanishes practically in the ensuing 12 hours. One may note that the second and subsequent exhaustion usually show smaller nucleations than the first, as though it were possible to reduce the nucleation faster than it is restored. It is probable therefore that in the first experiments something like an emanation escaped from the ground joint or that the outside of the aluminum tube had become radio-active during filling. Nevertheless, a residual effect is in evidence in the last experiments made, which can not be explained away. Something has escaped through the aluminum tube which produced the lingering radio-activity of the chamber (fig. 37).

EXPERIMENTS WITH DUST-FREE AIR ENERGIZED BY THE X-RAYS.

37. Persistence of nuclei produced by X-rays in the lapse of time.—The nuclei produced by the X-rays of sufficient intensity (*i. e.*, when the bulb is near the fog chamber), if left without interference, are indefinitely persistent as compared with the initial ionization. Table 23 shows some incidental results. It is not possible to determine the law of decay (probably exponential) by this method, as the nuclei are lost or otherwise destroyed by the condensation which determines their number. The initial nucleation must therefore be inferred. Again, the first coronas (if the X-ray bulb is at one end of the fog chamber as was here the case) are apt to be distorted, so that the corona obtained on first exhaustion is not available for definite measurement. To some extent the datum is supplied by the corona of the second exhaustion (s_2), observed after the fog particles of the first corona (s_1) have subsided, filtered air slowly replacing the exhausted air. m refers to the precipitation of water per cubic centimeter, at the pressure differences shown by the subscripts.

Within an hour or more after the exposure the coronas are invariably strong. Within 16 minutes, 36 minutes, even 85 minutes, they show diminutions of aperture comparable with that usually observed in the case of other nuclei. In half an hour the nucleation has not fallen below ½, in an hour not below ¼, etc. After 4 hours, however, all nuclei within the scope of the exhaustion have vanished.

TABLE 23.—Decay of X-ray nucleation in lapse of time. Exposure, 3 minutes; 6 cells. $\left\{ \begin{array}{l} n_{12}, n_{17} = .82. \\ n_{14}, n_{17} = 1.00. \end{array} \right\}$ Goniometer close up.

Time.		δp.	s'_1.	s'_2.	$10^{-3} \times n'_1$	$10^{-3} \times n'_2$	$10^{-3} \times n_1$	$10^{-3} \times n_2$
h.	*m.*							
	16	13.5	6.9	3.0	80	6.6	66	5.4
4	0	13.5	0.0	......	......	....	0	.0
	0	13.5	6.0–7.0	3.5	68	11	56	9
	36	16.7	4.7	1.5	28	1.4	28	1.4
	0	16.7	*Spindle	5.6	......	4.6	......	46
1	25	16.7	3.8	1.2	15	1.1	15	1.1

* Narrow spindle throughout A side.

TABLE 24.—Fog limits obtained with X-ray nuclei. X-ray bulb at different distances. Exposure for different times. Line of sight 15 cm. from end of fog chamber. Goniometer close up.

Remarks.	Time of exposure.	Distance from chamber.	δp.	s.	$n \times 10^{-3}$.
	Min.	*cm.*			
Current on....	2	35	18	0.0	0
off....	......	......	22	.8	1.0
off....	......	......	23	.8	1.0
off....	......	......	*25	1.4	1.7
off....	......	......	25	1.4	1.7
on...	2	35	24.8	7.0	110
on...	2	35	21.7	5.0	39
on...	2	35	20.1	2.9	9.4
on...	2	35	18.0	0.0	0
off...	......	......	20.1	0.0	0
off...	......	......	21.7	0.0	0
off...	......	......	23.3	0.0	0
Fog limit ...	......	......	19	......	....
Current on....	2	10	20.1	2.9	....
on....	......	......	18.5	1.4	....
Fog limit ...	......	......	18	......	....

Remarks.	Time of exposure.	Distance from chamber.	δp.	s.	$n \times 10^{-3}$.
	Min.	*cm.*			
Current on..	2	2	†18.5	4.5	26
on..	....	....	16.5	4.1	17
on..	....	....	14.9	0.0	0
Fog limit ...	....	....	15.5	......	......
Current on..	4	2	14.9	5.3	36
on..	4	2	11.9	5.2	28
on..	4	2	8.9	0.0	0
Fog limit ...	....	....	10	......	......
Current on..	8	10	18.5	3.1	8
Fog limit ...	....	....	‡17	......	......

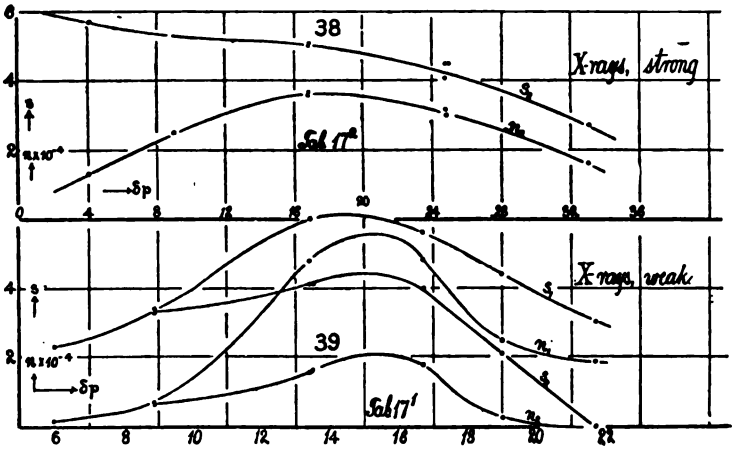
* Spontaneous condensation in dust-free air. † Distorted coronas. ‡ About.

38. Fog limits of nuclei produced by X-rays.—To obtain lower fog limits than were producible with the weak radium above employed, the following experiments with the X-rays (table 24) were undertaken. Even here the radiation is not strong (coil with 4-inch spark gap and energized by 4 storage cells).

The following fog limits were made out with the aid of the same fog chamber of waxed wood, used above:

X-ray bulb from chamber.	Exposure.	Fog limit.
35 cm.	2 min.	$\delta p = 19$
10	2	18
10	4	17
2	2	15.5
2	4	10
2	10	Vanishing.

A few other cases will be added below, giving for stronger radiation at a distance of 2 cm. and for only 2-minute exposure fog limits at 5 and 4 cm. In each case the air was rigorously freed from dust by filtration before the exposure began. Hence the nuclei are due to the X-rays alone, and their size increases indefinitely with the intensity of the ionized field. Indeed as to size they eventually in no wise differ from phosphorus or other efficient nuclei, and require almost no supersaturation to induce condensation.



FIGS. 38–39.—Apertures (s) and nucleations (n) varying with the pressure differences (δp) for the case of persistent nuclei produced in dust-free air by the X-rays.

Table 17, referred to in figs. 38 and 39, will be found as table 27, p. 45.

39. Sudden exhaustion in the absence of condensation.—In many of the experiments the nuclei seemed to be destroyed by sudden exhaustion even when no condensation took place, the pressure differences lying below the fog limit. As this is an important question bearing on the flying to pieces of the nucleus, special investigations were made as detailed in the following tables. The point at issue may be stated definitely as follows: Let δp be the fog limit of the given gas saturated with moisture. Let $\delta p' > \delta p$ be a pressure difference producing strong coronas. Let $\delta p'' < \delta p$ produce no condensation at all in the dust-free gas (below the fog limit). Then if the fog chamber is exposed to radiation in a definite way, in a definite time, and thereafter left without interference, $\delta p'$ will produce coronas for hours after the radiation ceases. If, however, immediately after the exposure $\delta p''$ is applied, producing no condensation, and if (dust-free air being introduced at once), without loss of time, $\delta p'$ is now applied, will coronas appear or will they not appear in spite of the excessive exhaustion? In other words, has the nucleus returned to dust-free air?

Thus, in table 25, experiment 1 shows that mere lapse of time has no relatively important effect. In experiments 2 and 3, the first exhaustion at $\delta p = 18$ has all but destroyed the corona, for $\delta p = 25$ subsequently applied, which should, by experiment 3, have been $s = 7.0$ cm. Similar remarks apply to experiment 4. Experiments 5 and 7 instance the usual case, that if a corona is produced in the first exhaustion, there will always be a smaller one in the second exhaustion. These are the favorable experiments; but experiment 6 and others which might be added show that the effect of the lower exhaustion does not disrupt the nucleus for the higher exhaustion. Thus there is no trustworthy evidence for the flying to pieces of the nucleus, and, in fact, the next section (table 27) shows that X-ray nuclei sustain high sudden exhaustions without being dissipated or failing to produce condensation. The difficulties encountered are without doubt referable to the variability in action of the X-ray bulb.

TABLE 25.—Possible rupture of the nucleus.

First exhaustion.		Time elapsed.	Second exhaustion.	
δp.	s.		δp.	s.
		Min.		
......	......	3	20.1	3.7
18	0.0	......	25	*1.3
......	......	......	25	7.0
6	(†)	2–3	13.4	2.6
13.4	6.0	2–3	13.4	4.1
6	(†)	2–3	13.4	4.5
13.4	5.8	2–3	13.4	3.4

*Spontaneous condensation. †Thin drifting fog.

Experiments were also made under satisfactory conditions with the bulb at 80 cm. (table 26). But the nuclei so obtained are essentially fleeting and would vanish without the first exhaustion.

TABLE 26.—Attempted breaking to pieces of nuclei. Bulb axial at 80 cm. from end. Exposure, 3 min. Fog-limit air, $s = 1.0 \ldots\ldots 1.5$ at $\delta p = 24.7$; with X-rays originally: $\delta p = 24.8$, $s = 3.8$. Filter with wet-sponge tube.

δp_1.	s_1.	δp_2.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
24.8	3.9	24.8	1.5	30.0	2.7
22.1	3.0	22.1	.0	11.3	.0
19.7	.8	24.8	1.8	1.1	3.1
19.2	.0	24.8	2.1	.0	4.3
24.8	3.6	24.8	.8	24.7	1.4
19.2	.0	24.8	1.0	.0	1.8
19.1	.0	24.8	1.5	.0	2.7
24.8	*3.3	24.8	†1.5	18.5	2.7

* Exposure, 7 min: $\delta p = 24.8$, $s = 3.6$.

† Accidental influx rapid and large: $\delta p = 24.8$, $s_3 = 2.8$, $s_4 = 2.4$, $s_5 = 0.8$.

40. X-ray nuclei at different high-pressure differences.—The following experiments originated in a somewhat similar purpose to the preceding section. In table 27, s_1 and s_2 show the apertures of the coronas on first and second exhaustion, filtered air being added in the meantime, after an exposure to relatively weak radiation. The apertures are a maximum at $\delta p = 15 - 17$ cm., after which they decrease faster than the increased precipitation on the nuclei warrants (fig. 39). The n-curves and the s-curves with increasing δp are both similar. As the final fall of curve depends on the difference of the opposed effects of larger precipitation and greater number of particles within the range of condensation, the very small nuclei must here be in absence.

TABLE 27.—X-ray nuclei at different pressure differences. Distance of bulb from apparatus, 3 cm.

Interval of exposure, 5 min.					Exposure, 3 min.				
δp.	s'_1.	s'_2.	$N_1 \times 10^{-3}$	$N_2 10 \times^{-3}$	δp.	s'_1.	s'_2.	$N_1 \times 10^{-3}$	$N_2 \times 10^{-3}$
21.7	3.0	0.0	12.5	.0	24.7	8.0	4.4	180	45
19.0	4.4	2.1	33.7	3.4	24.7	8.0	4.1	180	37
16.7	5.6	4.0	61.9	23.2	33.1	5.0	2.7	102	15
13.4	6.0	4.1	58.6	19.5	24.7	8.0	4.4	175	46
8.9	3.3	3.3	7.4	7.4	16.7	(†)	5.0	......	47
6.0	(*)	2.3	(*)	1.3	8.9	(†)	5.3	......	28
13.4	5.5	4.1	46.4	19.5	4.0	(‡)	5.7	......	14
					16.7	(†)	5.0	......	46

*Thin drifting fog. † Long spindle. ‡ Floating veil.

Corresponding experiments given in the second part of the table were therefore made with more powerful radiation (fig. 38). Here there is a regular decrease of aperture from the beginning where pressure differences are vanishing to the end where they are very high. The nucleations nevertheless pass through a determined maximum at about $\delta p = 16$ to 20 cm. The endeavor was made to guard against variation of efficiency of the X-ray bulb and other causes by repeated redetermination of the fiducial pressures. The fog limit of dust-free air is $\delta p = 24.7$ here. Hence it is noteworthy that the computed nucleation decreases at the highest pressure differences in spite of the accession of air nuclei to augment the number of X-ray nuclei present. The figures (38, 39) show the changes of n; but the reduction to N (nuclei per cubic centimeter at normal pressure) adds nothing new to the results.

To determine the nucleations for the high exhaustions is precarious, because the efficiency of the apparatus in producing truly adiabatic conditions will rapidly grow less, and because the data needed for the vapor pressure of water 20° or more below freezing are not forthcoming. A method of quadratic extrapolation had to be used in the present table. Indeed, with the possibility of temperatures below freezing even after the condensation of the water vapor, the whole phenomenon becomes very complicated. Hence the values of N in table 27 are mere estimates for values of δp exceeding 20 cm.

It may be observed, in conclusion, that in all the above cases the X-radiation was cut off some minutes before the exhaustion, so that persistent nuclei are alone in question, to the exclusion of the fleeting nuclei discussed in the next chapter.

CHAPTER III.

CRITICAL CONDITIONS IN THE FORMATION OF IONS AND OF NUCLEI.

The present chapter is a close continuation of the last, and is separated from it for convenience in treatment. Dust-free air, energized or not by radiation, is always in question. The subject considered in the earlier paragraphs is a comparison of fleeting and of continuous nuclei and the passage of one form into the other either by increasing the strength or quality of the radiation, or by solution. The effect of both methods in changing the fleeting into the persistent form is possibly the same. Afterwards the inquiry is reversed and the radiation itself examined in terms of the nucleation produced. It is noteworthy that penetrating radiation is a powerful nucleator.

41. Apparatus—X-ray bulbs.—A number of medium-sized bulbs of German pattern, about 10 cm. in diameter with an anticathode 2 cm. in diameter, were used. The differences between these were no greater than the differences between the same bulb after varying periods of action. The table summarizes a few data. There seems to be a voltage at which the nucleation (N) produced is a maximum.

TABLE 28.—Comparison of different bulbs. Pressure difference $\delta p = 25$ cm. X-ray bulb 200 cm. from fog chamber. Exposure, 3 sec. Exhaustion during exposure. Bulbs 10 cm. diameter. Anticathode 2 cm. diameter, except No. 2, which was smaller.

Bulb.	Bulb vacuum.	Coronal aperture. s_1.	Nucleation. $N \times 10^{-3}$.
No. 0 (used above)	Low.	5.0–6.0	60–110
1	High.	5.5	87.6
2 (small)	"	5.5	87.6
3	"	5.8	101.0
4	"	5.8	101.0
4 with lead plate; 0.14 cm.	"	3.8	30.0

The radium referred to was a weak sample (10,000×), 0.01 gram of which inclosed in a hermetically sealed tube of thin aluminum (walls 0.1 mm. thick) sufficed for the experiments.

42. Fog chambers—Filters with saturator.—The long rectangular fog chamber (Chapter II, section 16) of capacity $v=13{,}000$ cc., having the volume ratio $v/V=0.13$ to the volume V of the vacuum chamber, was largely used. It is often difficult, however, to keep plate-glass windows perfectly tight. Hence the cylindrical fog chamber (length 45 cm., diameter 12 cm.) was substituted for it, in which case $v/V=0.06$. Both the former and the latter were often incased in sheet lead, 0.14 cm. thick, leaving merely an open strip in the broadsides for observation of the coronas.

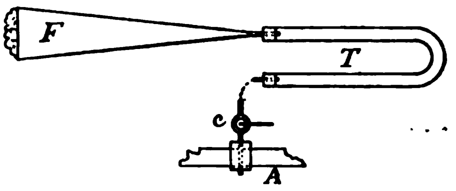
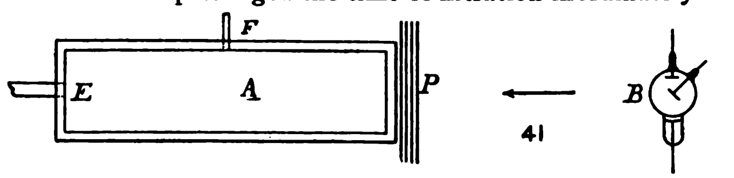


FIG. 40.—Filter with wet-sponge tube (saturator).

In view of the difficulties encountered in the preceding chapter, the attempt was finally made to counteract the effect of periodicity by saturating the filtered air with water vapor before introducing it into the fog chamber. To do this the U tube, figure 40, filled with pieces of wet sponge was added to the filter F, the filtered air from B entering the fog chamber very slowly by way of the stopcock C. This innovation seemed at first to be remarkably successful, as the results of table 29 on page 50 will show. Later, however, there was a very definite recurrence of periodicity, the true cause of which I ultimately traced to the inevitable formation of water nuclei. In addition to the filter mentioned, an ordinary dry-cotton filter and a Pasteur filter were often used; but the latter was soon discarded, as it gave no additional freedom from dust and prolonged the time of filtration inordinately.



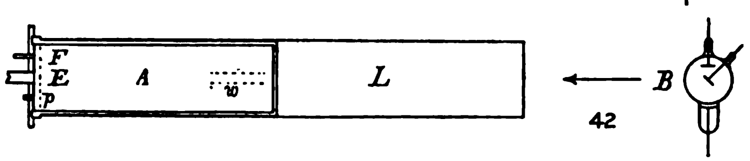
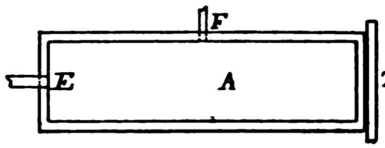


FIG. 41.—Rectangular wood fog chamber A, with screening lead plates P and X-ray bulb B, exhaust pipe E, and filter pipe F.

FIG. 42.—Cylindrical glass fog chamber A, with lead case L and bulb B. E is the exhaust pipe, F the filter pipe, p the plug for cleaning, and w the window.

43. Notation.—As above, the angular diameters, ϕ, of coronas will be given in terms of s, where $30 \times \sin \phi/2 = s/2$, as the arms of the goniometer are 30 cm. long; usually $\phi = s/30$, nearly. To secure clearer vision, the goniometer was moved up to the plate-glass window, placing the eye somewhat over 30 cm. off. The source of light, however, was left at 250 cm. from the trough, as above, and a correction applied for the distances.



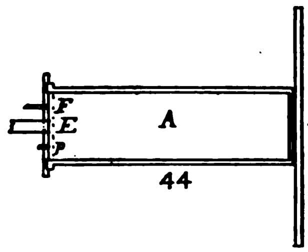


FIG. 43.—Rectangular fog chamber A, with lead tube T, filter pipe F, and exhaust pipe E.

FIG. 44.—Cylindrical fog chamber A, with lead tube P, exhaust pipe E, filter pipe F, and plug p.

In the tables, n usually denotes the number of nuclei per cubic centimeter of the exhausted air, N the number per cubic centimeter of the air at normal pressure and temperature. In successive exhaustions, without fresh nucleation, the apertures will be written $s_1\ s_2\ s_3 \ldots.$ and the nucleations corresponding $N_1\ N_2\ N_3 \ldots\ldots$ If, however, fresh nuclei are added, or if the exposure to the radiation is continuous, $s_1'\ s_1''\ s_1'''$ and $N_1'\ N_1''\ N_1'''$ are usually used. The difference of pressure in centimeters of mercury between the inside and the outside of the fog chamber (taken at 76 cm.) is denoted by δp. Hence if p' is the vapor pressure of water vapor, the corresponding volume expansion is $(76-p')/(76-p'-\delta p)$. D denotes the distance of the source of radiations (X-ray bulb, etc.) from the end of the fog chamber nearest it. δp_0 usually refers to the fog limit, *i. e.*, the pressure difference, below which there is no condensation in saturated dust-free air, within the scope of measurements made by aid of coronas. L shows the time elapsed between the end of the exposure to radiation and the condensation.

EFFECT OF LARGE PRESSURE DIFFERENCES.

44. Nuclei in dust-free air not energized.—In table 29 periodicity has been all but wiped out, and the incoming and outgoing series lie as nearly on a curve as may be expected.

TABLE 29.—Fog limit and effect of pressure difference for combined filter and wet-sponge tube. Dust-free air, not energized.

δp.	s.	$N\times 10^{-3}$	δp.	s.	$N\times 10^{-3}$	δp.	s.	$N\times 10^{-3}$
24.8	2.3	5.2	......	2.2	5.3	24.7	1.3	2.4
......	1.7	3.0	28.0	3.0	15.1	23.3	r	.0
......	2.1	4.4	29.7	3.1	18.0			
......	2.1	4.4	......	3.0	16.4	Pasteur filter dry.		
......	2.1	4.5	33.0	3.0	18.4			
22.6	.0	.0	38.0	3.1	24.9	25.0	1.5	2.7
24.2	1.0	1.8	38.0	3.1	24.9			
25.5	1.4	2.5	33.8	3.2	24.1	Cotton filter dry.		
26.4	2.7	11.1	30.5	3.2	21.2			
......	2.2	5.3	27.3	2.7	11.1	25.0	.8	1.4

The data for aperture, s, reach a limit as δp continually increases; but beyond the highest pressure difference applied, s will probably again decrease. N therefore must continually increase within the limits observed, but beyond them it will also eventually decrease (curves 45 and 46).

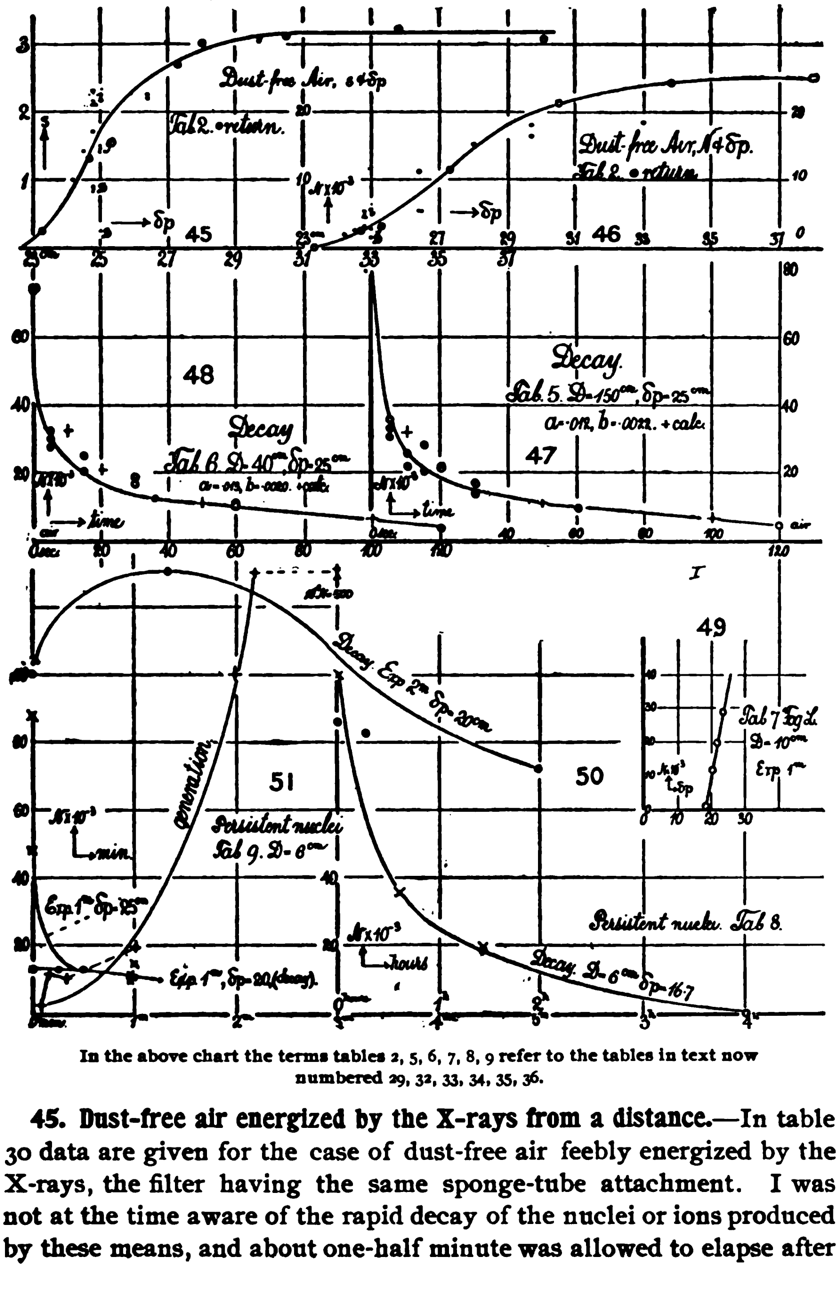
Incidental observations show the relative effect of a cotton filter without the sponge tube (D, figs. 45 and 46) and of the Pasteur filter, P. The former is apparently more efficient in its filtrations than the Pasteur filter, which has the additional disadvantage of being too slow for purposes of the present kind (period of influx prolonged over 10 minutes).

Curiously the fog limit of dust-free air is reduced by the sponge tube, lying in the given apparatus below $\delta p = 23$ cm. for rain and below $\delta p = 24$ for cloud. Such precipitations therefore cease when the volume increase on expansion in the two cases is respectively below 1.45 or just below 1.48, data which are naturally larger than C. T. R. Wilson's (Phil. Trans. Royal Soc. 1897, vol. 189, p. 265), in view of the differences of the apparatus employed. The reduced fog limit with the wet-sponge tube may be referable to increased supersaturation, but there is probably some specific cause yet to be investigated.* The highest nucleations observed lie within $N = 25,000$, which is very far below the conditions at which axial colors occur.

The following chart (figs. 45–51) illustrates tables 29, 32, 33, 34, 35, 36. "*Exp.*" refers to time of exposure to radiation; "δp," to lapse of time after radiation ceases. D is the distance of the ionizer (X-ray bulb or radium tube) from the nearer end of the fog chamber.

* It will be shown elsewhere that the (*very slow*) rate of filtration is here essentially in question.

δp is the pressure difference observed after exhaustion. The ordinates are often merely distributive or show the number of an observation in a series. The fog chambers are wood or glass as specified.



In the above chart the terms tables 2, 5, 6, 7, 8, 9 refer to the tables in text now numbered 29, 32, 33, 34, 35, 36.

45. Dust-free air energized by the X-rays from a distance.—In table 30 data are given for the case of dust-free air feebly energized by the X-rays, the filter having the same sponge-tube attachment. I was not at the time aware of the rapid decay of the nuclei or ions produced by these means, and about one-half minute was allowed to elapse after the exposure to the radiation before the observation was taken. The resulting apertures are thus reduced, about two-thirds of the nucleation having vanished; but they are otherwise comparable and much smoother than in the absence of a lapse of time, L, between the end of the exposure and the condensation. Two successive exhaustions are often made for the same exposure, for which N_1 and N_2 are the nucleations reduced to air at normal pressure.

TABLE 30.—Fog limit and effect of pressure difference for combined filter and wet-sponge tube. Dust-free air energized by X-rays. Observation after lapse of about 30 seconds.

Part I.—Bulb 80 cm. from end of fog chamber; exposure, 3 min.					Part II.—Bulb 150 cm. from end of fog chamber; lapse, 30 sec.				
δp.	s_1.	s_2.	$N_1 \times 10^{-3}$	$N_2 \times 10^{-3}$	δp.	s_1.	s_2.	$N_1 \times 10^{-3}$	$N_2 \times 10^{-3}$
20.9	2.1	......	3.6	......	20.9	r 1.7	†r 1.5	2.5	2.3
24.8	4.0	*2	32.0	3.8	24.8	3.9	1.3	29.6	2.3
28.9	4.0	3.1	38.7	17.4	28.9	3.7	......	33.0	......
33.0	(†)	3.2	......	23.2	33.0	4.0	2.9	47.2	16.6
37.1	4.0	......	53.3	......	37.1	3.7	3.0	45.4	21.7
41.2	3.7	......	53.8	......	41.2	3.1	3.2	§30.4	32.4
37.1	3.7	......	45.4	......	41.2	3.3	......	37.4	......
33.1	4.1	......	49.3	......	41.9	3.2	......	45.2	......
28.9	3.8	......	35.8	......	48.0	......	2.8	......	23.1
24.8	3.8	......	30.0	......	37.1	3.3	......	30.6	......
20.9	1.8	......	2.6	......	33.0	3.5	......	33.5	......
19.2	.0	......	.0	......	28.9	3.8	2.7	35.8	11.7
19.7	.8	......	1.1	......	24.8	3.3	r 1.0	18.3	1.8
22.1	3.0	.0	11.3	.0	24.8	**1.3	......	2.4	......
					24.8	††5.4	......	83.4	......
					24.8	‡‡3.8	......	30.0	......

* Air nuclei. ‡ Nonenergized air. ** Lapse, 3 min. ‡‡ Lapse, 30 sec.
† Accidental delay. § Same as air not energized. †† Lapse, 0 min.

In the first part of the table (curves 52, 53), while the values of s_1 and s_2 reach a limit, the nucleations N_1 and N_2 continually increase and are about $N = 25,000$ apart throughout the whole range $\delta p = 25$ to 41 cm. N_1 shows the number of nuclei left in dust-free air about half a minute after exposure to the X-rays; N_2 presents the case of dust-free air.

The second part of the table is irregular. The mean curves, however, preserve the same relations at first, the nucleations of the energized air being 25,000 in excess. Toward the end of the curves both the energized and nonenergized air show apparently decreased nucleation, while the former falls to the low values due to the normal air nuclei alone. The X-ray excess has been quite wiped out at $\delta p = 41$ cm.

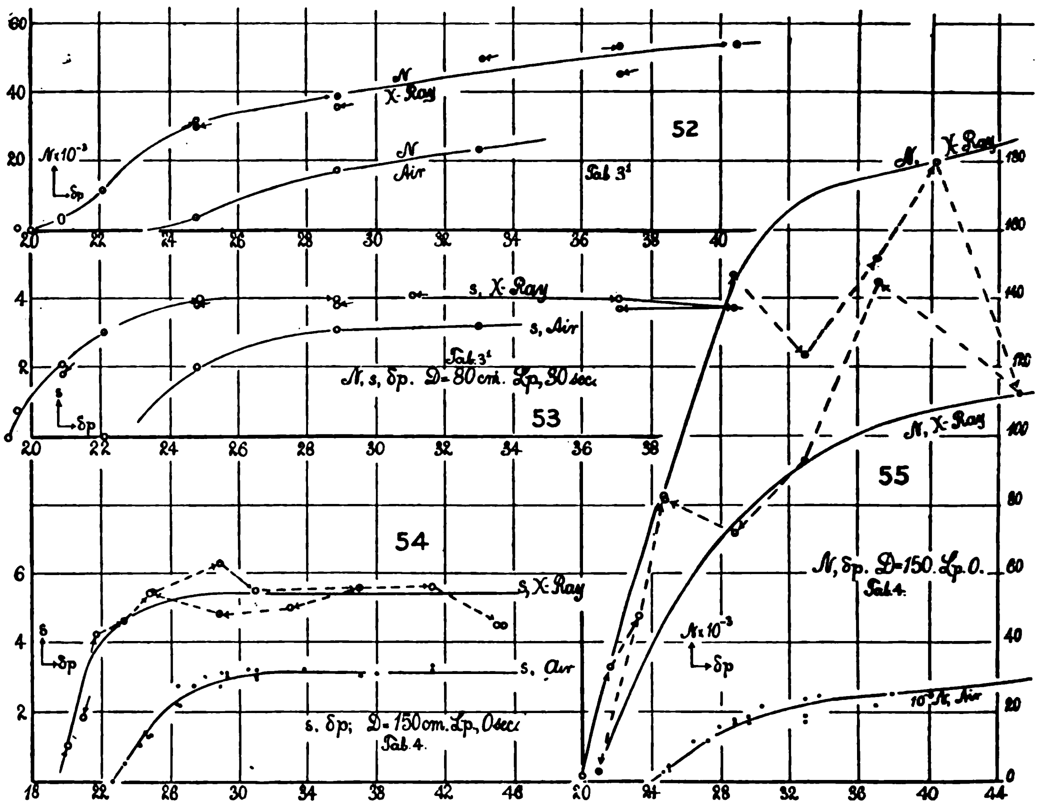
At the end of the table the preponderating effect of lapse of time after exposure is indicated. All excess of nuclei is gone after 3 minutes, while the original excess of 83,000 is reduced almost two-thirds in half a minute.

46. Continued—Rays not cut off during condensation.—Table 31 (curves 54, 55) contains data for the coronal apertures obtained without cutting off the radiation until after condensation has been produced. The two minutes' interval of exposure is excessive (as the following paragraphs show) when weak radiation (distance of X-ray bulb from end of fog chamber, $D=150$ cm.) is in question. The results in table 31 are distributed cyclically, and the return series shows less nucleation in general than the outgoing series. This is attributable to the gradual temporary loss of efficiency of the X-ray bulb. Similarly the fog limit is slightly below 20 cm. in the outgoing series and slightly below 21 cm. in the return series, the rise being toward the nonenergized dust-free air ($\delta p_0 = 24$ cm.).

TABLE 31.—Fog limit and effect of pressure difference for combined filter and wet-sponge tube. Dust-free air energized by X-rays. Bulb 150 cm. from end of fog chamber. Exposure, 2 min. Observation taken *during* exposure, or lapse, 0 sec.

δp.	s_1.	s_2.	$N_1\times10^{-3}$	$N_2\times10^{-3}$	δp.	s_1.	s_2.	$N_1\times10^{-3}$	$N_2\times10^{-3}$
20.0	r 1.0	......	1.3	......	45.4	4.5	......	112	......
21.7	4.2	......	32.5	......	41.2	......	3.3	....	36.3
23.3	4.6	......	47.5	......	37.1	5.5	......	144.1	......
24.8	5.4	......	82.2	......	33.0	5.0	......	92.7	......
28.9	6.3	......	147.0	......	28.9	4.8	......	71.7	......
33.0	5.5	......	123.1	......	24.8	5.4	......	82.3	......
37.1	5.6	......	151.3	......	20.9	1.8	......	2.6	......
41.2	5.6	......	179.4	......					

In addition to this, the outgoing and the return series show a curious case of periodicity which may or may not be real; but it is probable that there is decreased nucleation after δp exceeds 40 cm. The initial increase of N with δp is nearly straight and exceedingly rapid ($\delta N/\delta p = 15,000$, nearly). This is somewhat greater than the above values for radium (about 12,000), but of the same order as the datum for weak X-ray radiation. The corresponding data for dust-free nonenergized air, given in the same chart, show that initially $\delta N/\delta p = 5,000$, nearly, in correspondence with the earlier data so far as can be made out. The nucleations N are throughout small as compared with energized air, the excess in the latter case, if mean values be taken, being of the order of 100,000 nuclei per cubic centimeter.



FIGS. 52–55.—Illustrating tables 30, 31.

Tab. 3, in the above chart, is replaced by the present table 30 in the text; Tab. 4, by the present table 31.

GENERATION AND DECAY OF NUCLEI.

47. Fleeting nuclei.—This brings the work to the main purposes of the present paper, viz, to compare the generation and decay of the nuclei produced by the X-rays when the density of ionization or of electrification has different values. It was shown conclusively above that with strong radiation the nuclei persist for hours, and it follows from the foregoing paragraphs that for weak ionization they are fleeting. Hence there must be transitional conditions, and these are to be investigated, both for the production and for the decay of nuclei.

With such an end in view a strong X-ray tube may be placed at different distances from the end of the fog chamber and the results referred to the nucleation within, or the same bulb in the efficient and the partially fatigued condition may be placed at a fixed distance near the apparatus. The second method is usually inseparable from the first.

Data are given in table 32 *et seq.*, the pressure difference being chosen at the fog limit of dust-free air, which under these conditions contributes but a few per cent of the nuclei. The first part of table 32 shows that the origin of nuclei is practically instantaneous. Within 5 seconds after the radiation from the X-ray bulb (placed at $D=150$ cm.) begins, the air within the fog chamber is saturated with nuclei (curve 47).

Decay is not quite instantaneous, but enormously rapid as compared with the care for intense radiation of the preceding chapter. The number of nuclei per cubic centimeter is reduced one-half in about 2 seconds and reduced one-fifth in 20 seconds. After 120 seconds the nucleation of dust-free air is practically regained. The decay is not apparently exponential in character. If $N=N_0\epsilon^{-at}$, the data of tables 32 and 33 are badly reproduced. With $N=N_0/(1+b't)$ or $1/N=a+bt$, the agreement is as good as the observations. Hence $-dn/dt=bn^2$, or the decay is as the square of the number, showing that the destruction is mutual between the nuclei as if they were positive and negative ions.

TABLE 32.—Generation and decay of the nuclei. X-radiation, bulb at $D=150$ cm. $\delta p=25$ cm. Filter and wet-sponge tube.

I. Generation.

Time of exposure.	s.	$N\times 10^{-3}$
Sec.		
*0	r'1.5	3.0
30	5.3	79.0
15	5.5	87.6
†5	5.4	83.4
*0	1.0	1.8

II. Decay.

Time after exposure.	s.	$N\times 10^{-3}$
Sec.		
5	3.8	30.0
5	4.1	35.0
5	4.0	32.4
10	3.4	21.2

II. Decay.

Time after exposure.	s.	$N\times 10^{-3}$
Sec.		
10	3.6	25.0
15	3.7	27.6
15	3.6	25.0
20	3.4	21.2
20	3.4	21.2
0	5.6	92.0
30	‡2.0	3.8
30	3.0	13.2
30	3.2	16.6
30	3.2	16.6
60	2.6	9.2
60	2.6	9.2
120	2.2	5.0
120	2.1	4.4
0	5.4	83.4
0	‡4.8	60.0
0	4.8	60.0
5	‡3.2	16.6
5	4.0	32.4

* Dust-free air not energized. † Nucleation produced instantly.
‡ Note the low apertures after full corona.

TABLE 33.—Continuation of the preceding. Bulb at 40 cm. $\delta p = 25$ cm.

I. Generation.

Time of exposure.	s.	$N \times 10^{-3}$
Sec.		
0	r 0.8	1.4
60	5.2	74.4
15	5.2	74.4
*5	5.2	74.4
0	8.8	1.6

II. Fog limit at 20 cm.

δp.	s.	$N \times 10^{-3}$
21.6	3.0	11.1
20.1	1.5	2.2
18.4	0.0	.0

III. Decay.

Time after exposure.	s.	$N \times 10^{-3}$
Sec.		
5	3.8	30.0
5	4.0	32.4
5	3.7	27.6
15	3.4	20.4
....	3.6	25.0
60	2.7	10.0
....	2.8	11.0
120	2.0	3.8
30	3.3	18.6
....	3.2	16.6
0	5.6	92.0

* Nucleation produced instantly.

TABLE 34.—Continuation of the preceding. Bulb at 10 cm.

I. Generation. $\delta p = 20.1$. (Rays on.)

Time of exposure.	s.	$N \times 10^{-3}$
Sec.		
15	2.1	3.4
60	3.1	11.4
120	3.4	15.9
5	1.9	2.8
5	2.0	3.0
15	3.2	? 12.9
5	1.2	1.7
5	.0	.0
5	.0	.0
30	2.8	8.6
30	2.3	4.2
60	3.0	10.3
120	3.4	15.9

II. Decay. Exposure 60 sec. $\delta p = 20.1$.

Time after exposure.	s.	$N \times 10^{-3}$
Sec.		
15	1.7	2.5
10	1.9	3.0
5	2.3	4.2
0	3.1	11.4

III. Fog limit. 1 min. exposure. (Rays on.) Fog limit, 18 cm.

δp.	s.	$N \times 10^{-3}$
20.1	3.1	11.4
18.4	.8	.8
21.6	3.5	19.2
23.3	3.9	28.5
24.8	4.9	63.0

IV. Generation. $\delta p = 24.8$. (Rays on.)

Time of exposure	s.	$N \times 10^{-3}$
Sec.		
5	4.0	34.4
5	4.5	48.0
60	4.5	48.0
5	4.5	48.0
60	4.7	56.0

V. Generation. $\delta p = 20.1$.

Time of exposure	s.	$N \times 10^{-3}$
Sec.		
15	2.1	3.4
60	3.1	11.4
120	3.4	15.9

If N be expressed in thousands per cubic centimeter, the following is a summary of the results obtained:

		0 sec.	20 sec.	60 sec.
First series, $a=0.0128$, $b=0.0020$...	observed.............	78	19	8
	calculated...........	78	19	7
Second series, $a=0.0120$, $b=0.00218$	observed.............	83	18	7
	calculated...........	83	18	7

The effect of periodicity is still in evidence, seeing that the large coronas are apt to be followed by relatively small coronas. Some special results are given in the table. The coronas at these distances are round, but blurred, showing the occurrence of nuclei of all sizes.

At $D=40$ cm. (table 33 and curve 48), the results are not essentially different. The X-ray bulb is weak at first, but seems to recuperate in the course of the work. In other respects the two curves are essentially the same, as the above data show. In spite of the variability of the X-ray bulb, the insignificant differences of nucleation in these two cases are astonishing, for the distances vary from 40 to 150 cm. The law of inverse squares would predicate a fourteen-fold decrease. In fact, the same anomalous result seems to hold quite up to the fog chamber, as suggested in the data of table 34.

The bulb in table 34 is unfortunately weaker, showing only about half the nucleation of the preceding case ($N=48,000$ at $\delta p=24.8$ cm., for instance) in spite of greater nearness ($D=10$ cm.). The earlier data may have been larger, $N=63,000$ being among these. The fog limit has been definitely reduced from 20 cm. to 18 cm.

Generation is now no longer instantaneous; certainly not at $\delta p=20.1$, though the data at the larger pressure difference $\delta p=25$ are not decisive. It takes at least 2 minutes for the given radiation to saturate the air with nuclei corresponding to $\delta p=20.1$. (See curve 51.)

In conformity with the slow generation of nuclei the period of decay is now definitely prolonged. In 3 to 4 minutes the nucleation is reduced one-half.

48. Persistent nuclei.—The data for stronger radiation, showing remarkably persistent nuclei by comparison, have already been given in Chapter II, section 37 *et seq.*, and are repeated in the annexed curve (50). Roughly, the reduction is one-half in about 10 minutes and four-fifths in 80 minutes, contrasting sharply with the reductions in 2 seconds and 20 seconds, respectively, in the case of weak ionization.

TABLE 35. —Data for persistent nuclei. $D = 6$ cm.

Time of exposure.	Time after exposure.	δp.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
Min.	*h. m.*					
5	0	13.5	*7.0	3.5	86.0	12.7
	0 16	13.5	6.9	3.0	82.9	6.8
	4 0	13.5	.0	.0	.0	
5	0	16.7	*Spindle.	5.6	(100)	60.0
	36	16.7	4.7	1.5	36.4	1.8
	1 25	16.7	3.8	1.2	19.5	1.5

* Distorted.

Assuming the above equation $1/N = a + bt$, or $-dN/dt = bN^2$, for which, however, there is no immediate justification here and which does not fit well, values of the order of $a = 0.01$ and $b = 0.00001$ follow. The decay is thus shown to be several hundred times slower than above, under like assumptions.

In table 36 and curve 51 specific results for the generation and decay of nuclei have been added, obtained with a bulb strong at first, but eventually losing intensity below the necessary limit. The first part of the table shows a law of generation increasing with the time of exposure at an accelerated rate, consistently throughout the 180 seconds of observation. The remaining conditions have already been investigated in Chapter I. Measurement is difficult because of the distorted coronas, which soon become densely stratified fogs. The pressure difference used ($\delta p = 20$ cm.) is below the fog limit for air.

The curve (51) for nucleation (N) shows an enormously rapid increase after 1 minute of exposure, as though the nuclei themselves became radio-active, temporarily. This increase is sustained even if the radiation is cut off. (Section 56.)

The results for decay, in case of the persistent nuclei here obtained, are complicated and must be given in curves. In the second part of the table the minute exposures show but slight, if any, decay, in the absence of radiation, after the lapse of 1 minute. The 2-minute exposures actually seem to show increased nucleation in the minute succeeding exposure (secondary radiation, section 16); but in the ensuing 5 minutes after radiation, decay is manifest (curve 51). The behavior of the fatigued X-ray bulb may be contrasted with this, in the same position (part IV). The nuclei vanish as in the third part of the table, in spite of the 2-minute exposures as compared with the

1-minute exposures of the former case; and these inferences are corroborated by the last observation (part V) at the original low $\delta p = 20$ cm.

TABLE 36.—Continuation of the preceding. Bulb at 6 cm.

Time of exposure. (Rays on.)	Time after exposure. (Rays off.)	δp.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
			I. Generation.			
5 sec.	0 sec.	20.1	1.8	......	2.5	......
10	0	......	3.1	......	11.4	......
20	0	......	3.0	......	10.3	......
60	0	......	3.6	......	19.5	......
180	0	......	Strata (9.4)	5.5	(500)	68.3
60	0	......	3.6	......	19.5	......
120	0	......	Strata (5.4)	3.2	(100)	12.9
			II. Decay.			
60	0	20.1	3.2	......	12.9	......
60	15	......	3.2	......	12.9	......
60	30	......	3.2	......	12.9	......
60	60	......	*2.8	......	(4.4)	......
60	120	......	*3.0	......	10.3	......
120	120	......	Strata (6.0)	3.5	(130)	17.6
120	300	......	†5.6	3.0	71.8	10.3
			III. Decay. Larger δp.			
60	0	24.8	5.5	......	87.6	......
60	60	......	3.1	......	14.6	......
60	0	......	4.5	......	48.0	......
60	0	......	4.5	......	48.0	......
60	60	......	2.6	......	9.2	......
60	60	......	2.8	......	11.0	......
			IV. Decay.			
120	60	24.8	2.9	......	11.8	......
120	0	......	‡5.0	......	66.0	......
Bulb tested } 120	0	20.1	‡2.4	......	5.1	......

* Coronas distorted with much rain. Heavy fogs near bottom. Coronas more blurred and foggy as the time after exposure increases.

† Corona after 5 minutes' waiting, round; not stratified, but blurred.

‡ Bulb too weak for strata. Ionization density below entrance valve.

A comparison of the 1-minute exposures in parts II and III is noteworthy (curve 51). The high-pressure difference in part III ($\delta p = 25$) catches over four times as many nuclei as the low-pressure difference ($\delta p = 20$), *cæt. par.*, but the excess vanishes at once to the value of those within the reach of $\delta p = 20$ cm. Hence evanescent and persistent nuclei are always present together.

49. Persistence of fleeting nuclei after solution.—A result occurring throughout the observations is the following: Whether the nuclei are fleeting in character or not, there is invariably a second strong corona. This is obtainable on the succeeding exhaustion without fresh nucleation, even if the fog particles of the first corona are allowed to completely subside, before the addition of the dust-free air prior to the second exhaustion. If there were no first exhaustion during the exposure of the fog chamber to the radiation, no nucleation would have been found after the lapse of time needed preparatory to the second exhaustion. The reevaporation of fog particles from the first exhaustion, in every case changes about one-eighth of the fleeting nuclei into the stable nuclei observed in the second corona. This is obviously an important observation, bearing on the whole phenomenon of nuclei, condensation and rain.

To investigate this case the data of table 37 were collected, in which, as soon as possible after first condensation, dust-free air is admitted into the fog chamber to dispel the fogs by evaporation. When this is done the coronas on second exhaustion are invariably larger and denser (curves 56, 57), showing that more nuclei have been preserved, *i. e.*, converted from the fleeting into the stable form. The only effect producible by the premature influx is to diminish the number of fog particles lost by subsidence. It follows, then, that all nuclei upon which condensation has once taken place become stable nuclei.

It is somewhat difficult to measure the first corona and at the same time to provide for a quick influx of air so that but little subsidence of fog particles may take place. The data of table 37, therefore, quite apart from periodicity and other difficulties, can not be expected to be very uniform. It was not thought necessary to prolong the interval of persistence (time from influx of air to second exhaustion) beyond a few minutes, for these suffice to indicate persistence. The table shows that from 25 to 50 per cent of the nuclei may be preserved indefinitely by reevaporating them from fog particles. The mean datum of all results apart from the time interval entering the test is actually 39 per cent.

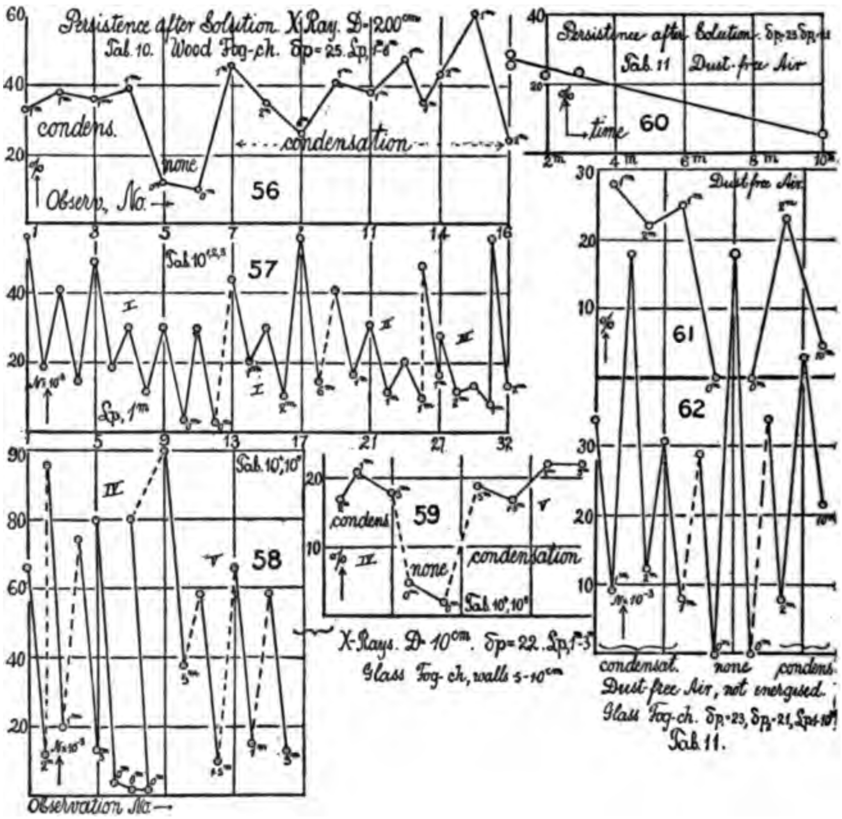
TABLE 37.—Showing that fleeting nuclei become stable on solution. Rectangular wooden fog chamber in lead casket. $\delta p = 25$ cm. Exposure to X-rays, 3 sec. Distance of X-ray bulb, 200 cm. Mere rain denoted by r.

Time elapsed after exposure to first exhaustion.	Time elapsed from first exhaustion to influx.	Time elapsed from influx to second exhaustion.	s_1.	s_2.	s_3.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
			Part I.				
Sec.	*Sec.*	*Sec.*					
0	0	60	4.7	3.3	*1.7	56.0	18.6
0	0	60	....	3.3	1.7	(49)	18.6
0	0	60	(4.3)	3.1	r	41.0	14.6
0	0	60	3.8	2.9	r	30.0	11.8
60	60	....	1.9	r	....	3.6	....
60	60	....	1.7	r	....	3.0	....
0	0	60	4.4	3.4	r	44.0	20.4
0	0	120	3.8	2.8	r	30.0	10.4
0	0	300	4.7	3.1	r	56.0	14.6
			Part II.				
0	0	60	4.3	3.2	r	41.0	16.6
0	0	60	3.9	2.9	r	31.2	11.8
0	0	60	3.4	2.6	r	20.4	9.8
			Part III.				
0	0	60	4.5	3.2	r	48.0	16.6
0	0	120	3.7	2.9	....	27.6	11.8
0	0	60	3.0	2.5	0	13.2	8.0
0	0	120	4.7	3.0	r	56.0	13.2
			Part IV. Cylindrical glass fog chamber. $\delta p = 22$. $D = 10$ cm.				
0	0	120	5.0	2.9	r	66.0	11.8
0	0	60	5.7	3.4	r	96.4	20.4
0	0	180	5.2	3.0	r	74.4	13.2
60	60	....	2.0	r	....	3.8	1.8
120	60	....	1.0	r	....	1.8	1.8
0	0	300	†6.7	3.7	r	146.6	27.6
			Part V.				
0	0	90	5.0	2.8	....	58.4	9.7
0	0	60	5.2	3.2	....	65.8	14.7
0	0	180	5.0	3.1	....	58.4	12.9

*Representing about 3,000 nuclei due to nonenergized, dust-free air.

† Persistence tested but not found (2-minute exposure, 1-minute lapse, $s = 1.0$).

The data of table 37 were at first obtained in the wooden fog chamber. It was thought advisable to repeat them with the cylindrical glass fog chamber, as this could be kept rigorously free from leakage (curves 58, 59). The mean results show that about 20 per cent of the particles persist indefinitely. This datum, which in any case is an inferior limit, is smaller here, because the amount of subsidence is relatively greater in a more shallow vessel. Without condensation, *i. e.*, in the absence of solution, only 2 to 5 per cent of the nuclei persist after 1 minute. With solution, the decay is not appreciably different in 1 to 3 minutes, showing that long periods of persistence are in question.



FIGS. 56–62.—Illustrating tables 37, 38.

Tab. 10 in the above chart is replaced by the present table 37; Tab. 11, by the present table 38.

50. Enlargement of nuclei in dust-free nonenergized air.—An exceedingly interesting correlative result is obtained by converting the nuclei of dust-free nonenergized air into solutional nuclei. Here the first exhaustion must necessarily be made at a pressure difference (say

$\delta p = 23$ cm. in the cylindrical apparatus) decidedly above the fog limit, so that a corona of appreciable size may appear. If this is dispelled on admission of filtered air by evaporation, the second corona may be obtained at a pressure difference ($\delta p = 21$ cm. in the table) below the fog limit, showing that large nuclei have been produced by evaporation. In the data of table 38, or in curves 61, 62, different intervals of waiting are tested, these intervals referring to the time elapsed (1 to 10 minutes) between the evaporation of the first corona and the condensation of the second. After 3 minutes about 25 per cent of the nuclei persist and require smaller exhaustions to induce condensation than the original nuclei. After 10 minutes about 5 per cent are left (curve 60), though a greater number of observations are here desirable. It should be noticed that without the preliminary condensation no condensation whatever would take place at the lower pressure difference.

TABLE 38.—Persistence in solution. Air nuclei. Fog chamber glass cylinder. $\delta p_2 = 23.2$; $\delta p_1 = 21.4$.

Time from first exhaustion at $\delta p = 23.2$, to influx.	Time from influx to second exhaustion at $\delta p = 21.4$.	s_1.	* s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.	Ratio.
Sec.	*Sec.*					
0	60	4.2	2.8	34	9.4	.28
0	120	4.9	3.1	58	12.4	.22
0	60	4.1	2.6	31	7.8	.25
† 60	30	4.0	0	29	.0	0
60	30	4.9	0	58	.0	0
0	180	4.2	2.6	34	7.8	.23
0	600	4.5	1.3	43	2.2	.05

* $s_3 = 0$ always tested. † Sufficient for complete subsidence.

51. Occurrence of water nuclei.—An explanation of the phenomena of the preceding paragraphs is not far to seek. Clearly the ions or fleeting nuclei go into solution, and the result on reevaporation of the fog particles is a solutional or water nucleus. Such a nucleus is obviously larger than the original nucleus or ion which furnishes the solute. Hence the condensation in the succeeding exhaustion must first take place on these residual nuclei, and they are therefore apt to capture all the available water. What makes the water nucleus stable is either the solute, by which the vapor pressure is reduced on continued evaporation to a degree equal to the excess of vapor pressure due to curvature, or possibly electrical potential may have a corresponding effect.

It is particularly interesting that if the nuclei or dust-free nonenergized air become the solute of water nuclei, that the new nuclei require pressure differences much below the fog limit of the original air for condensation, and the solutional nuclei are stable.

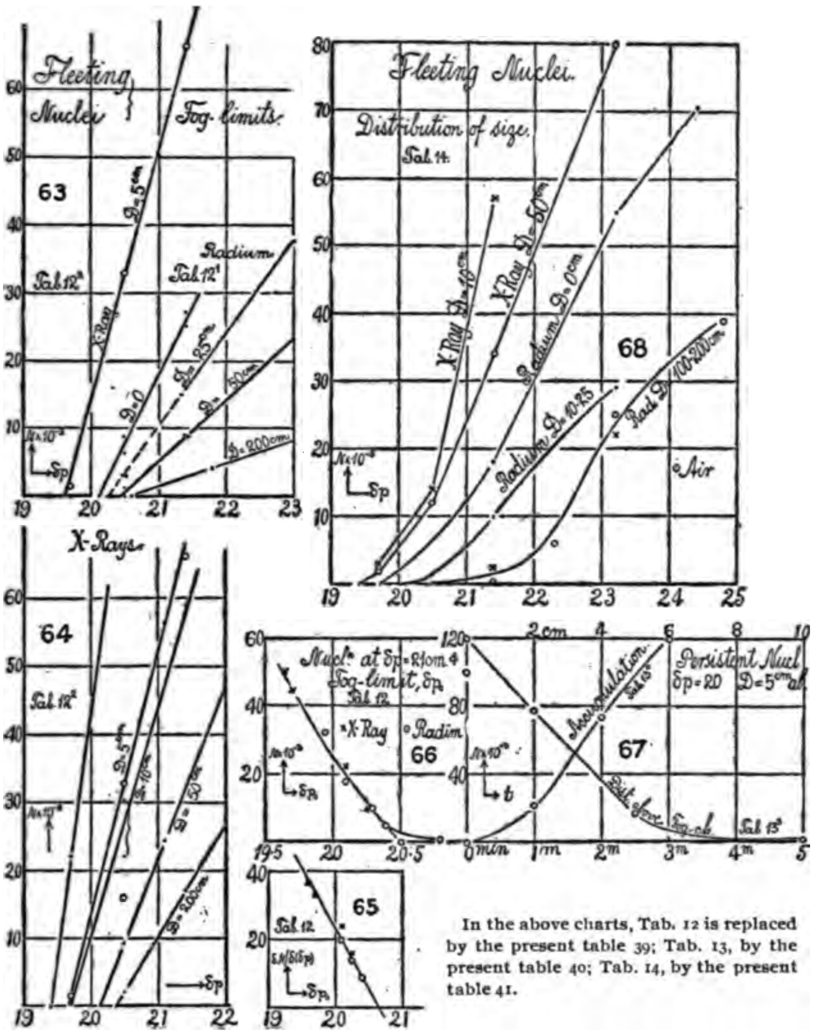
52. Cause of periodicity.—Very many of the occurrences which accompany condensation may be explained by the result just announced. In particular the alternations of large and small coronas (*cf.* Chapter II, sections 24, 27) so frequent throughout the present work are fully accounted for. The small fog particles, *i. e.*, those condensed on the smaller nuclei and caught near the end of the exhaustion, evaporate into the larger particles and become the water nuclei available in the next exhaustion.* Hence if the other condensation nuclei are all small, like those due to weak radiation or those normally present in air, the next condensation will take place on the water nuclei only. Thus a small inferior corona follows the large superior corona of the primary exhaustion. In the next exhaustion water nuclei will be absent, relatively speaking, and the condensation now occurs on all the small nuclei available for producing a large superior corona; and so on in succession. In general there are thus three groups of nuclei, x, y, z, concerned in any given condensation—a group, x, of water nuclei from the preceding exhaustion; a group, y, of nuclei belonging to the condensation in question and corresponding to the observed superior coronas; a group, z, of nuclei belonging to the same condensation, but which will evaporate their water and make the water nuclei for the next condensation. In case of periodicity the successive exhaustions would run,

1.		y_1	z_1	Superior corona on y_1.
2.	$x_2 = z_1$		$z_2 = 0$	Inferior corona on x_2.
3.	$x_3 = z_2 = 0$;	$v_2 + y_3$	z_3	Superior corona on $y_2 + y_3$.
4.	$x_4 = z_3$		$z_4 = 0$	Inferior corona on x_4.
5.	$x_5 = z_4 = 0$;	$y_4 + y_5$	z_5	Superior corona on $y_4 + y_5$.

etc. If the nuclei are fleeting the superior corona of the n–th exhaustion is condensed on y_n only, and under these circumstances, $y_n + z_n$, the total nucleation may often be replaced by $x_n + y_n$, or the total nucleation is the sum of the values belonging to the superior and inferior coronas. In this way the analysis of Chapter II, sections 28, 29, admits of easy interpretation.

53. Rain.—In any exhaustion the group $z_n = x_{n+1}$ are accountable for the rain which almost always accompanies coronal display. In such cases the water nuclei are comparable in smallness with the other nuclei, and the former are not able to capture all the available water.

* Incidentally the medium is kept saturated while temperature rises after exhaustion.



In the above charts, Tab. 12 is replaced by the present table 39; Tab. 13, by the present table 40; Tab. 14, by the present table 41.

FIGS. 63–68.—Illustrating tables 39, 40, 41.

54. Persistent nuclei in general.—It is not improbable that persistency may generally be due to some cause favorable to the production of water nuclei.* Those heavy rains, for instance, which accompany the X-ray corona when the bulb is close to the fog chamber may be due to the fact that condensation occurs spontaneously *without* the need of supersaturation, if an exposure to very intense X-light is in question. The nuclei in the X-field behave like hygroscopic bodies.

* For more detailed statements see my investigation on the "Structure of the Nucleus," Smithsonian Contributions, No. 1373, 1903.

TABLE 39.—Fog limits of fleeting nuclei. Cylindrical fog chamber, without casket. $s_2 = 0$, but tested.

Exposure to—	Distance.	δp.	s_1.	s'_1.	$N_1 \times 10^{-3}$.	$N'_1 \times 10^{-3}$.
	cm.					
I. Radium in aluminum	50	21.4	2.7	2.7	8.7	8.7
	....	20.5	.0	1.0	.0	1.4
	25	20.5	2.0	2.0	3.0	3.0
	....	19.7	.0	....	.0	....
	0	20.5	2.8	2.5	8.8	6.4
	....	19.7	.0	.0	.0	.0
	....	21.4	3.9	4.0	25.2	27.2
II. X-rays	200	21.4	3.4	....	17.1	....
	....	20.5	1.4	....	2.1	....
	50	20.5	3.4	2.9	16.3	9.4
	....	19.7	.0	.0	.0	.0
	10	20.5	4.2	3.7	30.4	22.1
	....	19.7	.0	.0	.0	.0
	5	20.5	4.3	...	32.8	....
	....	19.7	*r*	.0	1.4	....
	....	20.5	3.0	....	10.6	....
	....	21.4	5.3	....	66.3	....

TABLE 40.—Fog limits of persistent nuclei. Bulb above.

Exposure to—	Height of bulb.	δp.	s_1.	s_2.	N_1.	N_2.	Remarks.
	cm.						
III. X-rays, 3^m	.5	18.0	(*)	3.1	(83)	10.2	Radiation through earthed aluminum plate.
	.5	18.0	†(8.6)	3.5	(118)	15.8	
	2.0	18.0	†(6.1)	3.2	(78)	11.6	Do.
	5.0	18.0	*3.6	2.2	17.5	3.5	Do.
	10.0	18.0	*r*	.0	1.4	....	Do.
	3.0	18.0	‡2.4	....	4.6	....	Do.
IV. X-rays	.5	18.0	0	....	.0	.0	Exposure, 1 min.
	.5	19.7	3.8	*r*	22.2	1.5	Do.
	.5	19.7	*5.8	2.0	17.2	2.9	Exposure, 2 min.

* Oblong corona. ‡ After this, bulb (?) ceases to be efficient.
† Spindle or gourd-shaped corona.

		Fog limit	$\delta N/\delta(\delta p)$	N (at $\delta p = 21$)
	cm.	*cm.*		
Radium,	$D = 50$	Fog limit=20.4	$\delta N/\delta(\delta p) = 9 \times 10^{-3}$.	N(at $\delta p = 21$)= 5×10^{-3}.
	25	(20.3)	(14)	10
	0	20.1	20	18
X-rays,	200	20.3	16	10
	50	(20.1)	(24)	22
	10	(19.7)	(33)	44
	5	19.6	(36)	52

55. Gradation of size of fleeting nuclei—Fog limits.—The preceding observations, as well as the work of Chapter II, section 34, figure 34, make it probable that the fog limit varies slowly but definitely with the density of the ionization, while the rate, $\delta N/\delta(\delta p)$, or slope of the curves, *i. e.*, the increment of nucleation per centimeter of pressure difference, increases very rapidly. It makes little difference how the ionization is produced, whether by instantaneous exposure to the X-rays or to other radiation. In fact, the curves become nearly vertical in relative steepness. Additional experiments are nevertheless needed, and table 39 contains such results. In the first part radium (10,000×) in the thin aluminum tube is the energizer; in the second part, the X-rays perform a similar function more strongly. The results may be summarized in curves 63, 64, 65, 66, and as follows:

Both series are in general agreement and indicate the extremely slow depression of the fog limit (indicating the nuclei of maximum size) with the increase of number, $\delta N/\delta(\delta p)$ (fig. 65). In fact, the method for measuring δp is rather too crude to bring out the fog limits properly. They may be found from two consecutive measurements of N for two values of δp close together and near the fog limit. Figures 65 and 66 contain a comparison between the fog limits, δp_0, and $\delta N/\delta(\delta p)$, as well as N for $\delta p = 21$ cm., below the fog limit of dust-free air. They show the accentuated variation of the nucleations; but they announce also the decided variation of the fog limits for the case of fleeting nuclei, *i. e.*, that the maximum size of nucleus is a variable quantity among the gradations.

The last part of the table shows data for the persistent nuclei (curves 67). These were produced here by placing the bulb above one end of the cylindrical fog chamber, for the glass at the bottom was too thick to admit a sufficiently intense radiation. The inevitable difficulty in the investigation of these results is the weakening of the X-ray bulb in continued use. In a measure, this is a proof that electrical resonance or any more direct induction is not operative, for these effects would not vary with the past history of the bulb. Nevertheless, to avoid the possibility of such disturbances an earthed sheet of aluminum was adjusted to cover the top of the fog chamber. Experiments showed that all these precautions are unessential.

The curves (67) show the rapid decrease of the number of persistent nuclei with the height of the bulb (measured from the outside) above the cylindrical glass chamber (walls 0.3 cm. thick). They also show the extremely rapid increase of the nucleation with the time of exposure, suggesting radio-activity on the part of the nuclei as stated in section 56.

In table 41 the endeavor was made to determine the fog limit from two observations of N lying slightly above it. The work was very carefully done, but the data nevertheless fail to mark out definite loci. Beginning with the coronas for nonenergized air* (radium at infinity),

* The curve for air in case of high pressure differences is very difficult to determine, and will again be treated elsewhere.

which are always blurred and rainy, the probability of a curve doubly inflected near the fog limit is apparent, particularly if mean values be taken (curves 68).

Radium at $D = 200$ and at $D = 100$ cm. show data lying very nearly in this curve, but the last observations of the series prove that the fog limit is nevertheless definitely lower, or that the largest groups of nuclei are appreciably larger than the largest nuclei in dust-free non-energized air.

TABLE 41.—Fog limits of fleeting nuclei. Cylindrical fog chamber. $s_2 = 0$, tested.

Exposure to—	Distance.	δp.	s_1.	s'_1.	$N_1 \times 10^{-3}$	$N'_1 \times 10^{-3}$
	cm.					
I. Air	......	24.8	4.2	4.3	37.4	40.4
	......	23.2	3.7	3.6	25.3	22.9
	......	22.3	2.3	2.5	4.7	7.0
	......	21.4	.0	.5	.0	.8
II. Radium in aluminum tube	200	23.2	3.5	3.7	20.6	25.3
	......	22.3	2.2	......	4.4	......
	100	22.3	2.6	2.5	8.1	7.5
	......	23.2	3.4	3.5	18.7	22.5
	50	23.2	3.4	3.6	18.7	22.9
	......	21.4	2.7	2.7	8.7	8.4
	25	21.4	2.9	2.8	9.9	9.4
	......	23.2	4.0	3.9	29.7	28.3
	10	23.2	4.0	4.0	29.6	29.6
	......	21.4	2.8	3.1	9.2	13.1
	*0	21.4	3.1	3.4	13.1	17.1
	......	23.2	5.1	4.5	63.7	43.9
	†(Top)	23.2	4.8	4.9	54.9	56.7
	......	21.4	3.6	‡ 3.6	21.0	21.0
	200	21.4	1.8	1.8	2.7	2.7
	......	21.4	.0	.5	.0	.8
III. X-rays	50	19.7	1.2	......	1.7	......
	......	20.5	3.1	......	11.7	......
	......	21.4	4.2	4.8	31.9	50.4
	......	......	4.0	4.0	27.2	27.2
	......	23.2	5.5	5.7	80.1	88.2
IV	10	19.7	2.1	1.7	3.4	2.4
	......	20.5	3.0	3.5	10.5	18.1
	......	21.4	5.3	4.7	66.4	47.0

* Radium 15 cm. from line of sight.
† Radium 5 cm. from line of sight.
‡ Growth from $s = 3.3$ to $s = 3.8$; radium 5 cm. from line of sight.

Radium at $D = 10$ and at $D = 25$ cm. form a similar group with an obviously much lower fog limit, and the case is accentuated for radium at $D = 0$ cm. from the end, or 15 cm. and 5 cm. (on top) from the line of sight. At this point the data for the X-rays with the anticathode at distances $D = 10$ to 26 cm. form a prolongation of the series, showing further reduced fog limits and the probability of a doubly inflected curve of the same type throughout.

As a whole these observations corroborate what has already been inferred, that nuclei of all sizes are present simultaneously; that by far the greater number have a size depending on the density of the ionized field by which they are produced. These nuclei correspond to the steeper ascent of the curves. With this given, the exceptionally large nuclei at the lower end of the curve and the exceptionally small nuclei at the upper end bring about the double inflection, since the numbers of each gradually vanish. The more intense the ionization, the more nearly are the nuclei of the same size, while for weak ionization the gradation shown by the flat curves is accentuated.

56. Secondary generation.—In table 42 the endeavor was made to compare the effects of the X-ray bulb acting to produce persistent nuclei from different distances from the end of the fog chamber. Unfortunately dense stratified fogs occur in the first exhaustion, which makes it necessary to use the second exhaustion for the same nucleation as a means of measurement. The pressure difference $\delta p = 20$ cm. is below the fog limit, when air is not energized.

The first two parts of the table show the rapid decrease of N with increasing D; but it is particularly remarkable that after the lapse of 2 minutes subsequently to the exposure, the nucleation (*cæt. par.*) has apparently increased (curves 74, 76), precisely as if there were induced radio-activity in the nuclei, or in the apparatus, after the X-radiation has been cut off. The incessant danger from undersaturation is probably ineffective in view of the low-pressure difference. It follows, then, that the decaying nucleus is radio-active (for which reason probably the fleeting nuclei, though instantly generated, do not decay at the same enormous rates), or that the larger nuclei break up into smaller nuclei (increasing their number about threefold on the average), or that small nuclei beyond the range of the exhaustion gradually grow to a larger size.

Special experiments to bring out this feature of secondary generation were made in table 42 and in the third, fourth, and fifth parts of table 43. The phenomenon is put in evidence strongly on all cases, but with an additional result, showing a tendency in the alternations to disappear after several repetitions (curves 72, 73). The fifth part of table 43 shows the occurrence of secondary generation even for distances of 20 cm. between the anticathode and the fog chamber. The last datum is an indication of the growth of fog particles in the lapse of time (curve 75). In the fourth part of table 43 (curve 72) the alternations are a maximum, while the time elapsed after the exposure (4 minutes) is longest. The amplitude of the alternations is in all cases initially about 2.5 : 1, but it must be remembered that the coronas are observed after the second exhaustions. The nuclei caught in the first exhaustions may be estimated at 50,000 to 100,000.

TABLE 42.—Secondary generation.

Part.	δp.	D.	Time of exposure. (Rays on.)	Time after exposure. (Rays off.)	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
			Min.	*Min.*				
I.	20	6	2	0	Strata.	2.4	......	5.1
				2	"	3.4	......	15.8
				0	"	2.5	......	6.2
				* 2	"	2.5	......	6.2
				2	"	3.1	......	11.3
				0	"	2.1	......	3.4
				0	"	2.2	......	3.9
				2	"	3.0	......	10.5
II.	25	6	2	0	4.0	2.8	32.4	......
				1	Spindle 4.8	2.5	60.0	......
				1	4.9	2.3	64.0	......
				0	3.7	2.4	27.6	......
III.	25	6	1	1	3.9	2.1	32.0	......
				0	4.3	......	41.0	......

* Fails.

TABLE 43.—Continuation of the preceding. Secondary generation. *D*, distance of X-ray plate (anticathode) of bulb from end of fog chamber.

D.	Time of exposure. (Rays on.)	Time after exposure. (Rays off.)	δp.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
				Part I. Effect of distance.			
cm.							
5	120	0	20.1	Strata.	3.7	....	21.5
10	120	0	....	"	1.9	....	2.8
20	120	0	....	Fog.	.5	....	.6
				Part II. Secondary generation.			
5	120	120	20.1	Dense strata.	5.2	....	58.0
10	120	120	....	Strata.	2.8	....	8.5
20	120	120	....	1.0	....	....	(1.0)

TABLE 43, continued.—Continuation of the preceding.

D.	Time of exposure. (Rays on.)	Time after exposure. (Rays off.)	δp.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
			Part III. Secondary generation.				
5	120	120	20.1	Strata.	4.2	....	30.0
5	....	0	....	"	3.2	....	12.9
5	....	120	....	"	4.4	....	34.3
5	....	0	....	"	4.2	....	30.0
			Part IV.				
5	120	0	20.1	Strata.	3.6	....	19.5
....	....	240	....	"	5.0	....	51.5
....	....	0	....	"	3.6	....	19.5
....	....	240	....	"	4.3	....	32.0
....	....	0	....	"	4.0	....	25.0
			Part V.				
20	120	0	20.1	Veil.	....	Veil .0	....
....	....	120	....	2.9	....	9.2	....
....	240	0	....	3.5	....	17.6	....

In the first part of table 42 the alternations are promiscuous, but they fail but once in 8 observations (curve 71; failure at*). In the second part, where the coronas are nearly measurable, there is no failure (curve 70). The third part shows that exposures of 1 minute are not sufficient to bring out the phenomenon.

NUCLEATION DUE TO RAYS PENETRATING FROM A DISTANCE OR THROUGH DENSE MEDIA.

57. Effect of distance of the X-ray bulb from the free wooden fog chamber.—The probability of a residual effect in case where the X-ray bulb is moved to a considerable distance from the fog chamber is suggested by many of the above results. It is worked out in detail in table 44, where the condensations described were all made at the pressure difference corresponding to the fog limit of dust-free nonenergized air, and without cutting off the radiations. There is thus no decay. Nevertheless, the results are, as usual, disappointingly irregular, the first datum of each pair of results being low, the second high. Periodicity therefore occurs in spite of the wet-sponge tube added to the filter. The observed variation of results is moreover impossible in relation to distance, even though the data for inferior and superior coronas are apparently consistent in both outgoing curves. Again, in the return series inferior, superior, and mean coronas occur together. It would be difficult to conjecture any reason for the apparent minimum at $D=50$ cm. and the apparent maximum at $D=200$ cm., and they will presently be shown to be referable to the bulb. In any case, however, the mean decrement of nucleation within 6 meters is certainly less than one-fourth, evidencing an astonishingly small distance effect.

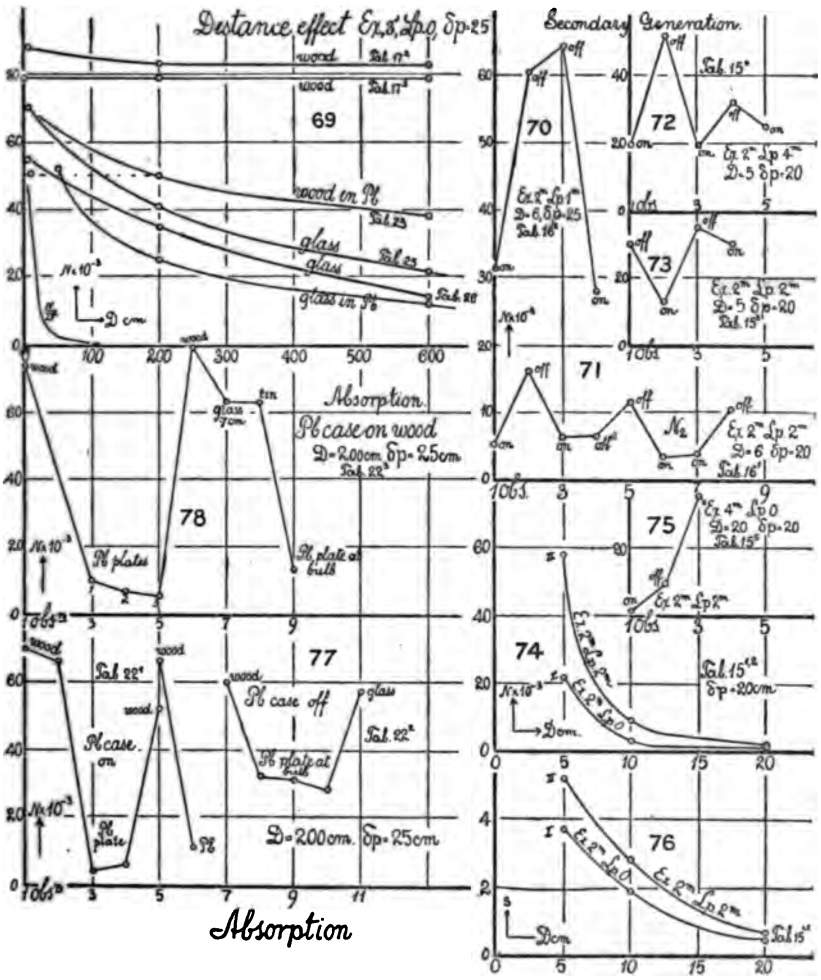
TABLE 44.—Nucleating effect of X-radiation from different distances; $\delta p=25$ cm. Time of exposure, 1 min., prolonged through condensation.

Part	D.	s_1.	s_2.	$N_1\times 10^{-3}$.	$N_2\times 10^{-3}$.	Part.	D.	s_1.	s_2.	$N_1\times 10^{-3}$.	$N_2\times 10^{-3}$.
I.	5	*5.1	2.5	69.6	8.0	II.	600	5.4	r	83.4	....
	50	2.0	1.3	3.8	2.4		200	5.4	r	83.4	....
	50	4.2	2.0	38.0	3.8		6	5.5	r	87.6	....
	100	3.4	2.0	20.4	3.8		†6	2.7	....	10.0	....
	100	4.1	2.0	35.0	3.8	III.	600	5.3	(‡)	79.0	....
	200	4.3	1.9	41.0	3.6		200	5.3	....	79.0	....
	200	4.9	2.0	64.8	3.8		6	5.3	....	79.0	....
	400	3.3	1.8	18.6	3.2	IV.	600	5.5	(‡)	87.6	....
	400	4.4	2.1	60.0	4.4		200	5.6	....	92.0	....
	600	4.0	1.6	32.4	3.0		6	5.6	....	92.0	....
	600	3.9	1.5	31.0	2.8	V.	6	6.3	3.1	123.0	14.6
	400	4.3	2.0	41.0	3.8		50	4.9	(‡)	64.0	....
	200	4.9	2.0	64.8	3.8		50	4.9	....	64.0	....
	100	4.5	2.0	48.0	3.8		6	5.2	....	74.4	....
	50	3.7	1.3	27.6	2.4		6	5.2	....	74.4	....
	5	4.0	1.7	32.4	3.1		50	6.0	....	112.4	....
	200	4.3	2.0	41.0	3.8		50	5.4	....	83.4	....

*7 cells in remaining experiments. ‡ Taken but not recorded.
† 1 minute after exposure.

To guard against variations of the tube, the abbreviated series were made as given in the second, third, and fourth parts of the table (upper curves 69); and these show what was to be expected from the preliminary results, that within the 6 meters of observation about the same nucleation is produced in the fog chamber (*cæt. par.*) irrespective of distance. Finally, part V of the table proves that the apparent minimum at $D=50$ cm. is an error.

The absence of a distance effect in the case of the nonincased wooden fog chamber is astonishing and implies that the space within the 6 meters of observation is everywhere equally full of the nucleus-producing radiation. This behavior, moreover, is different from the fluorescent, photographic, or even the electrical effect of the X-rays. Thus the phosphorescent screen is intensely illuminated at $D=5$ cm., while at 2 meters it is very dim and at 6 meters quite dark. It is natural to infer that the constancy of radiation is due to atomic disintegration of the platinum anticathode, when bombarded by the cathode torrent, and that the issuing rays are akin to the gamma rays of radium and quite distinct from the undulatory phenomenon of X-radiation. In fact, each part of the medium within the radius of 6 meters behaves as if it were the source of such rays.



FIGS. 69–78.—Illustrating tables 43, 44, 45, 49, 50, 53, 54.

58. Generation and decay for radiation from D = 200 cm.—Before proceeding with the investigation it will be advisable to examine the generation and decay of nuclei when the radiation comes from long distances. The data of table 45 are of the kind to be anticipated from the results of section 17. The experiments were made at the fog limit of dust-free air. The first part of the table shows that exposures of 1 and 2 minutes produce about the same nucleation, which vanishes with the lapse of 1 or 2 minutes after exposure to negligible residues. In the second part of the table the radiation is stronger and maximum nucleation appears after 3 seconds of exposure, so that the nucleation is produced instantaneously. Initial nucleations obtained (*cæt. par.*) in air which has been long stagnant are apt to be very low. The mean nucleation after less than 3 seconds' exposure is about 90,000 per cubic centimeter.

The effect of longer exposures is again investigated in the third part of the table, but the possibility of a slight increase of the nucleation in the lapse of time is negatived by the last observation. The fourth part also shows that fog limit to be at $\delta p = 20$ cm., and that there is no accumulation of nuclei as time goes on. There is no appreciable persistence.

TABLE 45.—Generation and decay of nuclei. $D = 200$. $\delta p = 25$ cm. Wood fog chamber.

Part.	δp.	D.	Time of exposure. (Rays on.)	Time after exposure. (Rays off.)	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
			Min.	*Min.*				
I.	25	200	1	0	4.2	1.7	38.0	3.0
			1	1	2.6	*r*	9.2	*r*
	25	200	2	0	3.7	1.7	27.6	3.0
			2	2	1.8	1.0	3.2	2.0
			Sec.					
II.	25	200	60	0	* 3.6	1.7	25.0	3.0
			5	0	6.1	2.4	115.0	6.6
			3	0	5.3	....	79.0	....
			3	0	† 4.3	....	41.0	....
			3	0	5.9	2.2	108.0	5.0
			3	0	5.7	2.0	96.4	3.8
			3	0	* 3.6	....	25.0	....
			3	0	5.6	2.8	92.0	10.4
			3	0	5.7	2.7	96.4	10.4
III.	25	200	10	0	4.9	....	63.0	....
			10	0	4.2	....	38.0	....
			30	0	5.2	....	74.4	....
			30	0	5.2	....	74.4	....
			60	0	5.3	....	79.0	....
			60	0	5.4	2.6	83.4	9.2
			3	0	5.1	....	69.6	....
IV.	20	200	3	0	*r*	*r*	*r*	*r*
			30	0	1.7	....	2.6	....
			60	0	1.7	....	2.6	....
			120	0	1.7	*r*	2.6	*r*

* After long waiting. Stagnant air. † Follows preceding high nucleation.

As a whole the observations for $D = 200$ are irregular, for the usual reasons instanced above.

59. Electrical effect for different distances.—To roughly estimate the state of the room in relation to the ionizing effects of the X-rays, the time of collapse of the gold leaves was taken, when the galvanoscope standing on an earthed brass plate was covered with a glass bell jar. Table 46 needs no explanation. In the second part of the table the time of collapse decreases about as the square of the distance and is thus quite different from the fog-chamber effect. At short distances the galvanoscope registers a sudden throw when the circuit through the X-ray tube is first made. The effect of this throw is the same as if negative electricity entered the metal frame of the electroscope, and it is therefore probably electrostatic induction on the brass foot plate coming from the cathodal conductor.

TABLE 46.—Electrical effects of X-rays. Galvanoscope in glass bell jar, walls 0.5 cm. thick.

D.	Remarks.		Time of collapse.
cm.			*Sec.*
200	Without screen *		<5
	With lead plate 0.14 cm. thick		10 – 15
	With semicylindrical lead screen and semicircular lid		30 – 40
	With glass bell jar on brass plate		>120
	With wide (7 mm. thick) glass plate		30
			Observed.
15	+ charge: impulsively increased divergence; then collapse, computed		Instantaneous.
	— charge: impulsively decreased divergence; then collapse, computed	0.2 sec.	<1
50	+ charge * / — charge	2	3 – 4
100	+ charge / — charge	8	8 – 10
200	+ charge / — charge	30	25 – 30
600	+ charge / — charge	270	Say 300

* Positive and negative charges behave alike.

60. Apparent penetration of the X-rays coming from 600 cm.—The astonishingly small distance effect observed made it seem probable that the effective rays are of a penetrating kind. Table 47 (to be interpreted later) apparently bears this out, though in reality it merely separates the axial and lateral radiations. Advantage is taken of the sufficiency of short exposures whereby the tube is kept more constant. The apparatus is shown in figure 41, where A is the fog chamber and P the plates.

To take first the experiments in table 47, when the distance between the lead screen at the fog chamber and the X-ray bulb is $D = 600$ cm., which are smoothest (curve 79), it appears that a single lead plate 0.14

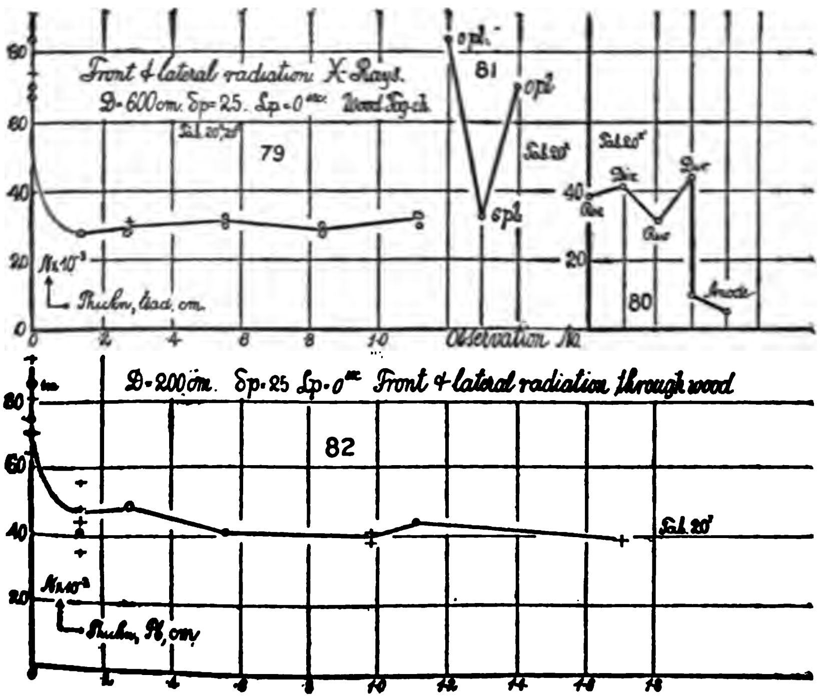
cm. in thickness is more than sufficient to reduce the nucleation one-half. Thereafter the remaining thicknesses up to 1 cm. or more does not reduce it further. A close comparison is given at the end of the work, in which $N = 76{,}000$ falls off to $N = 32{,}000$ for 6 plates, or a thickness of about 0.84 cm. (curve 81).

An interesting comparison is given for the efficiency of the X-ray tube radiating from this distance either from the front face of the anti-cathode or from the rear face of the anticathode, the tube in the latter case being completely reversed (curve 80). The mean results are respectively $N = 42{,}500$ and $N = 34{,}600$, showing the anticathode to behave as if it were transparent or at least radiating from both faces in all directions. Indeed, even if the anode and the cathode are exchanged (reversed current), considerable radiation is sent out; as, for instance,

Concave mirror the cathode, $N = 47{,}000$,
Concave mirror the anode, $N = 7{,}000$,

or about 16 per cent of the nucleation has been retained (curve 80).

The coronas obtained when lead screens are used in front of the fog chamber are clear and often multi-annular, showing the nuclei to be very nearly of a size.



FIGS. 79–82.—Illustrating table 47.
In the above chart Tab. 20 = present table 47.

TABLE 47.—Penetration of rays and reversal of tube; $\delta p = 25$ cm. Exposure about 3 sec. prior to condensation without cutting off the radiation; air, $s = 1.2$; wood fog chamber not cased (fig. 41).

Part.	D.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.	Remarks on penetration.
I.	200	5.4	3.2	83.4	16.6	Screens removed.
		5.4	....	83.4	....	Tin plate, 0.50 mm. thick.
		4.3	(*)	41.0	....	Lead plate, 1.4 mm. thick.
		4.5	....	48.0	....	Lead plate, 2.8 mm. thick.
		4.5	....	48.0	....	Lead plate, 2.8 mm. thick.
		5.4	....	83.4	....	Screen removed.
II[1].	600	5.2	....	74.4	....	Do.
		3.9	r	31.0	....	Lead plate, 2.8 mm. thick.
	600	4.2	r	38.0	....	Screen removed. Tube reversed.
		4.3	r	41.0	....	Screen removed. Tube directed.
		3.9	r	31.2	....	Screen removed. Tube reversed.
		4.4	r	44.0	....	Screen removed. Tube directed.
	600	2.6	....	9.2	....	Anodal rays.
		2.2	....	5.0	....	Do.
II.	600	4.2	r	†38.0	....	0 lead plate, 1.4 mm. thick.
		5.0	....	67.0	....	Do.
		‡3.7	....	27.6	....	1 do., thickness, 1.4 mm.
		3.7	....	27.6	....	Do.
		§3.7	....	28.0	....	2 do., total thickness, 2.8 mm.
		3.7	....	27.6	....	Do.
		4.0	....	32.4	....	4 do., total thickness, 5.6 mm.
		3.8	....	30.0	....	Do.
		3.8	....	30.0	....	6 do., total thickness, 8.4 mm.
		3.7	....	27.6	....	Do.
		3.7	....	28.0	....	Do.
		4.0	....	32.4	....	8 do., total thickness, 11.2 mm.
		3.8	....	30.0	....	Do.
		5.4	1.0	83.4	1.8	0 do.
		4.0	....	32.0	....	6 do.
		5.1	1.5	69.6	2.8	0 do.
III.	6	5.4	¶r	87.6	....	0 plate.
	6	5.3	....	79.0	....	1 plate.
	6	5.3	(2)	79.0	....	0 plate.
	6	5.3	(2)	79.0	....	1 plate.
IV.	600	5.3	(2)	79.0	....	1 plate.
	600	**4.0	(2)	79.0	....	0 plate.
V.	200	5.3	(2)	79.0	....	0 plate.
	200	5.3	(2)	32.4	....	1 plate.
	200	4.5	(2)	48.0	....	2 plates.
		4.3	(2)	41.0	....	4 plates.
		4.4	(2)	44.0	....	8 plates.
		5.1	(2)	69.6	....	0 plate.
		5.2	(2)	74.4	....	0 plate; 1 min. exposure; no growth.

* Second exhaustion made, but not recorded.
† Initial low datum.
‡ Galvanoscope discharged at 6 meters and through lead plate, but much more slowly than the instant collapse at 6 cm.
§ First plate filters out the axial rays. The remainder have no observable effect, and are virtually transparent. Coronas clear and multi-annular apart from rain.
¶ Second exhaustion necessary to avoid periodicity.
** Note the reduction of N at 600 for 1 plate, which does not occur at $D = 6$ cm. and $D = 200$ cm.

TABLE 47, continued.—Penetration of rays and reversal of tube, etc.

Part.	D.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.	Remarks on penetration.
VI.	7	6.4	2	129.0	....	0 plate.
		5.4	2	83.4	....	1 plate.
		5.3	2	81.2	....	2 plates.
		5.9	....	108.4	....	0 plate.
		5.7	....	96.4	....	4 plates.
		4.9	....	64.8	....	7 plates.
		5.6	....	92.0	....	4 plates.
		4.9	....	64.8	....	0 plate.
VII.	200	4.7	(*)	56.0	....	0 plate, thickness, 0.0 cm.
		4.9	....	64.0	....	0 plate, thickness, 0.0 cm.
		4.4	....	44.0	....	1 plate, thickness, 0.14 cm.
		4.1	....	35.0	....	1 plate, thickness, 0.14 cm.
		5.6	....	92.0	....	0 plate, thickness, 0.0 cm.
		5.1	....	69.6	....	0 plate, thickness, 0.0 cm.
		4.5	....	48.0	....	1 plate, thickness, 0.14 cm.
		4.7	....	56.0	....	1 plate, thickness, 0.14 cm.
		5.3	.. .	81.2	....	0 plate, thickness, 0.0 cm.
		4.2	....	38.0	....	7 plates, thickness, 0.98 cm.
		4.3	....	41.0	....	7 plates, thickness, 0.98 cm.
		4.2	....	38.0	....	12 plates, thickness, 1.68 cm.
		5.6	....	92.0	....	0 plate, thickness, 0.0 cm.
	600	5.5	....	87.6	....	0 plate, thickness, 0.0 cm.

* Taken, but not recorded. In the first two data the bulb is gaining strength.

61. Apparent penetration of the X-rays coming from 200 cm. and from 6 to 7 cm.—The results for $D = 200$ cm. are similar to the preceding. It again takes less than one lead plate (thickness 0.14 cm.) to stop the absorbable rays (curve 82). There is no extra thickness of lead as an equivalent of the layer of 400 cm. of air removed. Again, about one-half of the radiation is stopped by the first plate and greater thicknesses produce no further effect. At the end of the table a wall of lead 1.7 cm. thick shows no additional absorption. Moreover, tinned iron plate ½ mm. thick has no appreciable effect on the radiation whatever (curve 82).

The first experiments for $D = 6$ cm. show apparent previousness of the single lead plate (0.14 cm. thick); but this seems to be referable to the intensity of the initial radiation without the lead screen, for in the experiments at $D = 7$ cm., a single plate shows marked reduction of the very large coronas observed. On the other hand, a plate even 1 cm. thick absorbs very little of the radiation, for, roughly, about 80 per cent passes, in spite of the indefinite thickness of lead, between the bulb and the fog chamber, completely screening off the latter. The results throughout are curiously irregular and difficult to interpret, as seems not unexpected, since all secondary radiators must now be close at hand (curve 83).

TABLE 48.—Penetration; miscellaneous experiments on case of lead plates: 0.14 cm. thick; $\delta p = 25$ cm. Wood fog chamber.

Part.	D.	Rays on.	Rays off.	Number of plates.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
		Sec.	*Sec.*					
I.	7	3	60	0	2.7	....	10.4	....
		60	60	0	3.2	....	16.6	....
		120	60	0	Strata (5.7)	3.2	96.0	16.6
		120	0	0	Fog (5.0)	(2)	68.0	....
		120	60	1	Veil 2.7	1.4	10.4	2.6
		120	60	1	Veil 3.0	1.4	13.2	2.6
II.	7	180	60	1	Veil 3.0	....	12.2	....
		120	60	0	Strata (4.8)	3.4	60.0	20.4
		Case of tinned iron plate, 0.5 mm thick.						
III.	6	3	0	0	5.6	....	92.0	....
		180	0	0	Strata (6.8)	3.1	153.0	....
		180	120	0	Strata (7.1)	3.1	170.0	....
		180	0	1	5.8	2.3	101.0	....
		180	120	1	2.0	r	3.8	....
		3	0	0	5.8	(3)	101.0	....
		3	60	0	2.7	r	10.4	....
IV.	*6	120	60	1	2.9	r	11.8	r
		120	0	0	4.0	2.8	32.4	10.4

* Another bulb.

62. Generation through lead plate and through iron.—The data of table 48 show the usual accelerated increase of the nucleation, *N*, with the time of exposure, when nuclei of the persistent type are produced (curve 84). When, however, the lead screen (thickness 0.14 cm.) intervenes, there is no accelerated increase and no accumulation above a relatively small value, $N = 13{,}000$. These nuclei may be a transitional type, but it is difficult to interpret the case of very small coronas. Another similar test was made with a screen of tinned sheet iron ½ mm. thick. The results are in the main the same; in other words, marked persistent nucleation is not produced through the iron plate in spite of its slight thickness and lower density. Parallel observations for 3 seconds' exposure show that about as many nuclei are thus generated as are obtained after a 3-minute exposure through the plate.

On the other hand, for 3 minutes' exposure there is growth of nucleation, if observation is made 2 minutes after exposure; in the presence of the plate the nucleation falls off to a negligible datum in the same lapse of 2 minutes after exposure. The decrement in this case is of the same order as is observed for the short exposure (3 seconds) tested a minute after exposure ceases. The use of another bulb with the plate does not change the results.

FOG CHAMBERS INCLOSED IN METAL CASKETS.

63. Wood fog chamber in lead casket—Penetration.—In table 49 data of a crucial kind are given for the purpose of separating the radiation which actually passes the lead screens from that derived from secondary or lateral sources. The first part of the table is at once decisive (curve 77). Less than 7 per cent of the radiation which passes the wood and glass walls of the chamber will pass through the front face (toward the bulb), if this face is closed by a lead plate 0.14 cm. thick. When the chamber is freed from the casket and the plate placed at the bulb, more than half of the radiation gets into the fog chamber secondarily, as shown in the second part of the table and curve 77.

TABLE 49.—Wood fog chamber in a lead casket open in front, toward the bulb. D = 200 cm. 2ρ = 25 cm. Thickness of lead plate, 0.14 cm; of glass plate, 0.7 cm. Exposure 3 sec. Lapse, 2 sec.

Part.	Front of casket, etc.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
I.	Open, bulb a	5.1	1.7	69.6	3.0
	Open	5.0	1.5	66.0	2.8
	Closed by lead plate	2.0	....	3.8	5.0
	..... do	2.2	....	5.0	5.0
	Open	4.6	....	51.6	...
II.	Open, bulb c	5.0	1.7	66.0	3.0
	Closed by lead plate	2.8	....	11.0	5.4
	Casket removed	4.8	2.0	60.0	3.8
	Lead plate *at bulb*	4.0	1.7	32.4	3.0
	..... do	3.9	1.7	31.2	3.0
	..... do	3.7	1.7	27.6	3.0
	Glass plate	4.7	1.9	56.0	3.6
III.	Open	6.3	2.4	123.0	6.6
	..... do	5.2	1.7	74.4	3.0
	Closed by lead plate	2.7	2.7	10.0	10.0
	Closed by 2 lead plates	2.4	2.0	6.6	3.8
	Closed by 4 lead plates	2.3	2.6	5.4	9.2
	Closed by 0 lead plate	5.3	2.0	79.0	3.8
	Closed by glass plate	4.9	1.7	63.0	3.0
	Closed by tin plate	4.9	*r*	63.0	*r*
	Lead plate at bulb	3.0	2.4	13.2	6.6

With an improved and more fully lead-incased chamber, the data given in the third part of the table were investigated, in which successive thicknesses of 0.14, 0.28, 0.42 cm. of lead plate allow 14, 9, and 7 per cent of the radiation to pass (curve 78). The differences from the above datum are due to the greater intensity of the radiation here applied and to other incidental conditions. Furthermore, a glass plate 0.7 cm. thick, and a tinned iron plate 0.05 cm. thick, each allow nearly all the radiation to pass, *i. e.*, about 90 per cent, while a lead plate placed near the bulb at $D = 200$ cm. cuts off about 17 per cent of the radiation (curve 78).

Hence it follows in the above experiments with the lead envelope removed, since one-half of the radiation was cut off by a single frontal lead plate 0.14 cm. thick, that about half of the radiation enters the wooden fog chamber, not from primary, but from secondary sources (using this term in its broadest sense), through the lateral walls of the apparatus. When the chamber is inclosed in the lead case open in front, the inside walls of the lead become a source of radiation, so that the corona need not decrease in size, as the data show. In general, the behavior is such as if the whole medium between the bulb and chamber were equally "polarized" (to use this word with a special meaning). At the lower pressure difference ($\delta p = 20$ cm.) the lead plate proves to be quite impervious, but the tin plate certainly admits an accumulation of 3,000 nuclei.

64. Continued—Radiation from a distance.—Experiments made to find the effect if the distance, D, of the bulb from the lead-incased fog chamber, open toward the bulb only, are given in table 50.

TABLE 50.—Wood fog chamber in lead casket. Effect of distance, D. $\delta p = 25$ cm. Exposure, 3 sec; lapse, 0 sec.

D.	s_1.	$N_1 \times 10^{-3}$.	Mean.
cm.			
600	*4.0	32.4	38
....	3.7	27.6	....
200	4.9	62.0	50
6	4.3	41.0	50
6	4.8	60.0	....
200	4.2	38.0	....
600	4.4	44.0	....

* s_2 always taken, but not recorded. Usually $s_2 = 1.5$ cm.

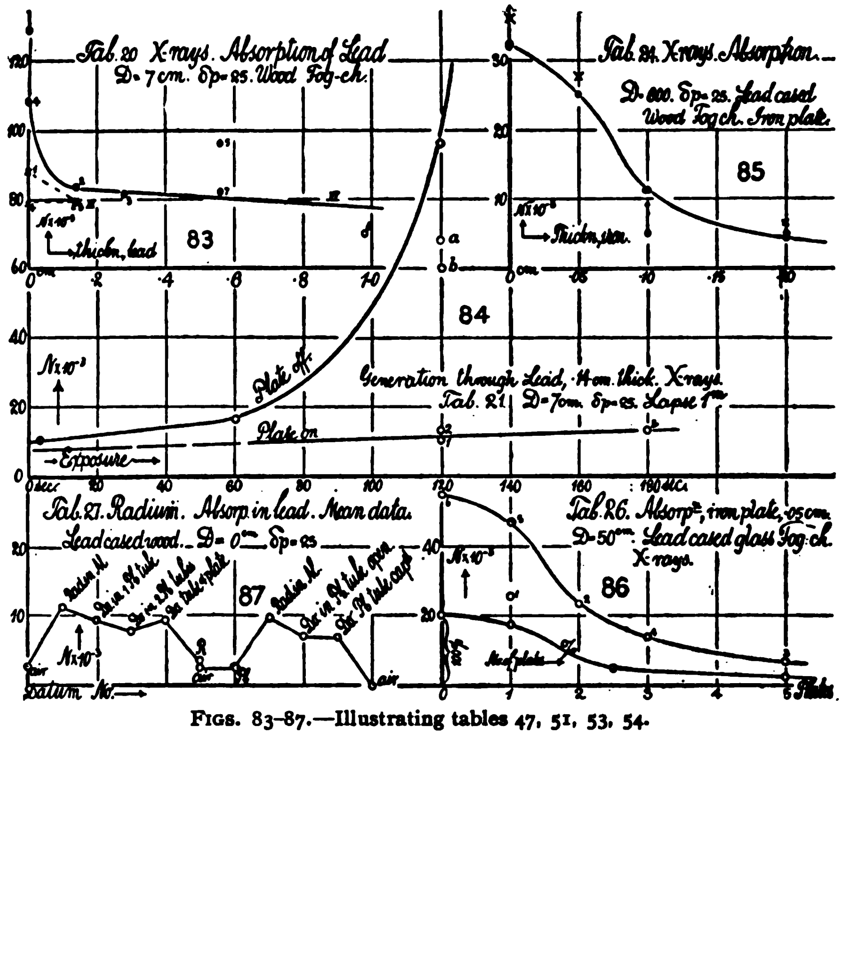
The bulb is as usual variable, but the nucleation produced is about the same for all distances up to 200 cm., after which there is a possible decrease of about one-fifth as far as 600 cm., the limit of observation (curves 69). This relatively insignificant effect of distance is again remarkable, inasmuch as all remote secondary radiation is excluded. Whatever produces the nucleation, if secondary, must come from the inside of the casket, or it must be primary. At all events it is again manifest that the whole medium within the room is almost equally energized throughout.

Table 51 and curve 85 show the penetration of tinned iron plates, each 0.5 mm. in thickness, when the X-ray bulb is 600 cm. from the lead-cased fog chamber. Several millimeters of iron plate are still appreciably penetrable even from this remote distance. So far as the data go the absorption is relatively marked between 0.5 and 1 mm. of thickness, the rates being much larger here than for greater or smaller thicknesses.

TABLE 51.—Penetration of tinned iron plates, 0.05 cm. thick. $D=600$ cm. $\delta p=25$ cm. Wood fog chamber in lead casket.

Number of plates.	Total thickness.	s_1.	$N_1 \times 10^{-3}$.	Mean.
	cm.			
0	0.00	* 4.0	32.4	32
1	05	3.6	25.0	25
2	10	2.2	5.0	8
2	10	2.8	11.2	....
4	20	2.2	5.0	5
4	20	2.1	4.4	....
0	00	3.9	32.0	36
1	05	3.7	27.6	28
2	10	2.8	11.2	11
4	20	2.4	6.6	7
0	00	4.3	41.0	....

* Second exhaustion made, but not recorded. Usually $s_2=1.0$.



FIGS. 83–87.—Illustrating tables 47, 51, 53, 54.

TABLE 52.—Distance effect of X-rays. Glass fog chamber. $\delta p = 22$ cm. (fog limit of air). No lead casket. Walls, 0.3 cm. Bottom 1 cm. thick.

Distance.	s_1.	s_2.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.
cm.				
200	4.6	* 1.6	51.6	3.0
	4.3	1.7	41.0	3.2
10	5.0	1.5	67.0	2.6
	5.0	1.5	67.0	....
600	3.4	1.5	20.4	....
	3.5	1.5	22.6	....
200	3.7	*r*	27.6	....
	4.4	*r*	44.0	....
10	5.3	*r*	79.0	....
	5.0	*r*	67.0	....

* Faint and small, due to dust-free air.

TABLE 53.—Distance effect of X-rays. $\delta p = 22$ cm. Lead plate 0.14 cm. thick. $s_2 = 0$, but always tested.

Distance.	Lead plates.	s_1.	$N_1 \times 10^{-3}$.	Distance.	Lead plates.	s_1.	$N_1 \times 10^{-3}$.
Part I. Cylindrical fog chamber, without casket.							
200	1	3.2	13.9	200	0	4.3	34.4
	0	4.8	50.4	10	0	5.0	55.4
	* 0	3.7	23.2	600	0	3.3	15.6
	1	3.8	25.2		0	3.1	12.2
Part II. Cylindrical fog chamber, lead-cased, with tubular end of lead 50 cm. long. (Fig. 42.)							
50	0	4.7	47.0	400	0	3.5	19.0
	1	1.8	2.7		0	3.6	21.0
	1	2.0	3.2	200	0	3.8	25.2
	2	1.8	2.7		0	4.1	29.4
	0	4.8	50.0	50	0	5.0	55.4
200	0	3.6	21.0		0	5.0	56.3
	0	3.7	23.2	50	1	1.5	2.3
600	0	3.0	11.1		1	1.5	2.3
	0	3.1	12.3				

Part III. Lead-cased fog chamber as before. Penetration through tinned iron plates 0.05 cm. thick.

Distance.	Tin plates.	s_1.	$N_1 \times 10^{-3}$.	Per cent transmitted.
50	1	3.8	25.2	46
	2	3.7	23.2	42
	5	2.5	6.7	12
	3	3.2	13.9	25
	1	4.7	47.0	86
		4.7	47.0	
	0	5.0	55.0	100

* Double glass envelope.

65. Glass fog chamber—Radiation from a distance.—The experiments on the nucleation produced by X-rays coming from a distance were now continued by aid of the cylindrical fog chamber (glass walls 0.3 mm. thick and 1 cm. thick at the bottom), the lead casket being here removed (curve 69). The data are given in table 52, and may be restated from the mean results,

$D = 0 + 30$ cm.	$N = 70{,}000$,
$200 + 30$	$41{,}000$,
$620 + 30$	$22{,}000$,

where N is measured from the line of sight, 30 cm. from the end of the fog chamber nearest the bulb. Very much of the lateral radiation is thus cut off by the thick glass walls and bottom of the fog chamber; but the decrements are far from suggesting the law of inverse squares even in a remote degree. As the distance from the line of sight increases over 20 times, N decreases only 3 times.

The repetition of these experiments with a less active bulb gave about the same results (table 53). For distances from the line of sight, $D = 20$, 210, 610, the average nucleation was $N = 55{,}000$, 34,000, 14,000. About one-half the total radiation is absorbed by a frontal lead plate, or a double glass envelope, as usual (curves 69).

66. Radiation from a distance—Glass fog chamber in lead case.—The endeavor was finally made to stop off all secondary radiation by providing a close-fitting lead tube (L, fig. 42), which not only incased the fog chamber A, but extended about 50 cm. beyond the end nearest the bulb. If distances are measured from the line of sight, the mean results may be estimated as $D = 60$, 210, 610 cm., corresponding to $N \times 10^{-3} = 52$, 25, 12. The nucleation falls off a little more rapidly than before (a part of which may be referable to imperfect alignment of the distant bulb), but after 200 cm. the decrease is slow (curves 69).

In the present case a single lead plate (thickness, 0.14 cm.) cuts off nearly all the radiation, *i. e.*, all but 4 to 6 per cent. Hence very little secondary radiation has entered, while the small penetration of the lead is probably referable to the distance of the plate from the end of the chamber (*cf.* distance effect for gamma rays, next paragraph). Compared with lead, the absorption of tinned iron is small (curves 86), the plates (eventually 0.25 cm. thick) allowing 26 per cent of the radiation to pass for the same thickness of plate which was used in the case of lead. This result is quite out of proportion with the relative densities.

NUCLEATION DUE TO GAMMA RAYS.

67. Lead-cased wooden fog chamber—Penetration.—In order to interpret the above data for X-rays, it will first be necessary to determine the facility with which nuclei are produced by very penetrating radiation. The radiation of radium filtered through lead walls about 1 cm. thick was therefore tested. Table 54 gives a series of results in which the radium (10,000×) was first tested when hermetically sealed in a thin aluminum tube and placed 6 to 10 cm. from the line of sight (curve 87). In this case the radiator nearly touched the free end of the lead-cased fog chamber *A* (fig. 43). The aluminum tube was then successively enveloped in one or more lead tubes, *T*, with wall 0.5 cm. in thickness. The length of the tubes exceeded the width of the fog chamber, and they were placed with their axes parallel to the plane of the end, so that any radiation entering would have to pass through the lead ; or, passing out of the lead tube, enter the fog chamber laterally under very unfavorable conditions. Leaving the latter case (which is here negligible) for further experiment, table 54 gives the coronal apertures s_1, s_2, s_3, etc., and nucleations N_1, N_2, N_3, etc., found in successive exhaustions under the conditions stated. The figures show that periodicity is a frequent and unavoidable occurrence. Many exhaustions were therefore made in each case and the means taken in triads. These are given in detail in the summary at the end of the table, and in the curve (87). Sometimes the particular adjustment of the tube (as, for instance, the position of the radium in the tube) seems to be of importance, for the results in any given position are fairly uniform. An additional lead plate is ineffective. The summary shows that of the radiation which escapes from the aluminum tube, 85 per cent passes through 0.5 cm. of lead and 70 per cent through 1 cm. of lead, assuming that there is no secondary radiation. In one case (tube capped by a lead plate) nothing at all seems to enter the fog chamber. This suggested the following group of experiments, which show that zero nucleation may occur periodically under any conditions.

68. Continuation.—The new results (table 54, part IV) show a curious irregularity, which is borne out by the behavior of radium when placed in the fog chamber (Chapter II, section 31). In the present case the tube was 60 cm. long (similar to *P*, fig. 44), parallel to the plane of the end (about 20 cm. across) of the fog chamber and placed close to it. The data for the open and closed tube are about the same. In both cases the values of *N* at times descend to the low nucleations of nonenergized air, though as a whole they lie pronouncedly above it. The lead tube without radium is inactive. Moreover, in the final part of the work all data are decidedly lower than at first, as if the energizing quality were fatigued. This occurs not only within the radium in lead tubes, sealed or not, but in the case where the radium is in the sealed aluminum tube only. The air values give evidence of an almost entire absence of nuclei. Reasons for this unsatisfactory behavior can not even be conjectured. The mean values given in thousands per cubic centimeter are: For air, $N^* = 2.6$; radium in open lead tube, $N = 22-12$; radium in capped lead tube, $N = 21-18$; air, $N = 2.2$; lead tube without radium, $N = 2.4$; radium in aluminum tube only, $N = 10$; radium in open lead tube, $N = 7$; radium in capped lead tube, $N = 7$; air, $N = 0$, remembering that the radium is in all cases surrounded by the sealed thin aluminum tube.

Apart from the fatigue it is clear that the open and capped tube behave alike, proving that the rays actually penetrate the walls and that secondary radiation is ineffective. This also follows from the next paragraph, as the distance effect of radium is marked. The amount of radiation passing 5 mm. of lead is here about 73 per cent, but the present result is not as good as the above.

TABLE 54.—Penetration of γ-rays of radium. $\delta p = 25$ cm. Lead-cased fog chamber. Radium in thin (0.1 mm.) aluminum tube, hermetically sealed. Walls of each lead tube 0.5 cm. thick. Plate, 0.14 cm. thick. $D = 6-10$ cm. Lead tubes parallel to walls of chamber, 20 cm. long.

Part.	Remarks.	s_1.	s_2.	s_3.	s_4.	$N_1 \times 10^{-3}$	$N_2 \times 10^{-3}$	$N_3 \times 10^{-3}$	$N_4 \times 10^{-3}$
I.	Radium in Al only	2.9	3.2	3.0	2.8	11.8	16.6	13.2	11.2 (11.8)
	Radium in lead tube	3.3	1.9	3.0	1.9	18.6	3.6	13.2	3.6
	Radium with 1 plate and tube	2.7	2.6	2.7	2.5	10.4	9.2	10.4	8.0 (10.4)
	Radium in lead tube	2.9	2.9	3.2	2.7	11.8	11.8	16.6	10.4
	Radium with reflector	1.0	2.1	2.0	......	1.8	4.4	3.8	......
	Radium in lead tube	2.6	2.6	1.5	2.3	9.2	9.2	2.8	5.4
	Radium removed	1.5	1.5	1.0	2.0	2.8	2.8	1.8	3.8
II.	Radium removed	1.4	2.2	1.7	1.0	2.6	5.0	3.0	1.8
	Radium in Al tube	2.7	2.8	2.0	3.2	10.0	10.6	3.8	16.6
	Radium in lead tube	1.8	2.7	3.0	1.5	3.2	10.0	13.2	2.8 (18.6)
	Radium in double lead tube	2.8	1.9	2.9	1.0	10.6	3.6	11.8	1.8 (5.4)
	Radium in double lead tube	1.0	3.0	2.2	3.3	1.8	13.2	5.0	18.6
	Radium removed	1.6	1.0	1.7	1.0	3.0	1.8	3.0	1.8

* Given in thousands per cubic centimeter.

TABLE 54, continued.—Summary.

Part.	Radium at ∞.	Radium in Al tube.	Radium in 1 lead plate; wall 0.5 cm.	Radium in 2 lead tubes; wall 1 cm.	Miscellaneous.	
					Tube and plate.	Tube and reflector.
III.	$N \times 10^{-3} =$ 2.5 2.5 3.9 2.7 2.4 2.4	14.5 11.9 8.8 8.7	9.8 8.4 13.0 13.9 7.6 5.0 9.1 9.3	7.4 5.2 8.3 10.5	9.8 9.2	3.6
	Means.. 2.7	11.3	9.5	7.9	9.5	3.6

TABLE 54, continued.—Tubes of lead 60 cm. long often capped. Wall, 0.5 cm. thick.

Part.	Remarks.	s_1.	s_2.	s_3.	s_4.	$N_1 \times 10^{-3}$	$N_2 \times 10^{-3}$	$N_3 \times 10^{-3}$	$N_4 \times 10^{-3}$
IV.	Air	0	1.7	2.0	2.0	0.0	3.0	3.8	3.8
	Radium in Al in lead tube with ends open	3.8	3.2	3.3	2.6	29.0	16.6	18.6	9.2
	Do	1.6	3.5	......	......	3.2	22.6	......	......
	Radium in lead tube capped	3.4	3.2	3.7	3.3	20.4	16.6	27.6	18.6
	Do	3.4	0	2.0	3.2	20.4	0	3.8	16.6
	Air	r	1.6	r	......	1.8	3.0	1.8	......
	Lead tube without radium	*r	1.9	r	......	1.8	3.6	1.8	......
	Radium in Al tube	2.9	2.0	3.0	......	11.8	3.8	13.2	......
	Radium in lead tube open	2.2	3.1	r	......	5.0	14.6	1.8	......
	Radium in lead tube capped	2.7	2.3	2.2	......	10.4	5.4	5.0	......
	Air	0	0	......	......	0	0	......	......

* No induced radio-activity.

69. Continued—Effect of distance.—Radiations from radium are in curious contrast with the corresponding results for the X-rays, inasmuch as the corresponding nucleating power falls off rapidly with the distance of the sealed aluminum tube from the fog chamber. At 200 cm. the effect is but just appreciable above the nucleation of nonenergized dust-free air, as shown in table 55.

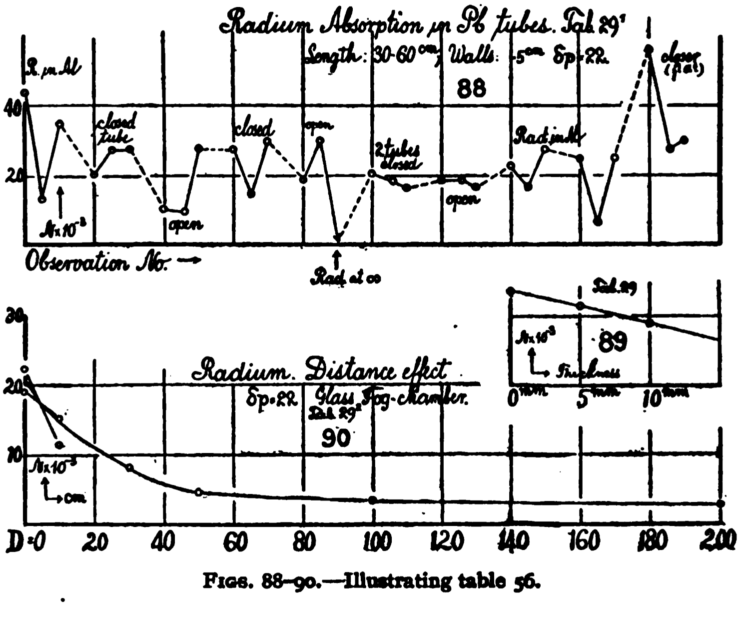
Marked excess of nucleation is observed within 100 cm., apparently increasing as the distance from the fog chamber decreases; but it is difficult to make definite statements here, because all the effects are small and successive exhaustions show marked periodicity. The mean values are estimates. Though 5 minutes of exposure was at first allowed, the effect is probably instantaneous and the succeeding sections show that the effect is very penetrating.

TABLE 55.—Radium effect from different distances outside of fog chamber. $\delta p = 25$ cm. Wood fog chamber in lead casket. First exposure 5 min. Radium in sealed aluminum tube.

D.	s_1.	s_2.	s_3.	$N_1 \times 10^{-3}$.	$N_2 \times 10^{-3}$.	$N_3 \times 10^{-3}$.	Mean $N \times 10^{-3}$.
cm.							
600	0.0	....	....	0.0	....	....	0
400	1.9	*r*	....	3.6	*r*	....	2
200	2.0	*r*	....	3.8	*r*	....	2
100	2.6	2.2	*r*	9.2	5.0	*r*	7
50	3.1	1.7	....	14.6	3.0	....	9
25	3.2	1.9	*3.1	16.6	3.5	14.6	10
10	3.0	*r*	*3.1	13.2	*r*	14.6	8
0	3.4	2.0	*3.3	20.4	3.8	18.3	12
∞	1.2	1.8	†*r*	2.2	3.2	*r*	2

* Five or six periods observed in succession, same amplitude.
† Radium effect lost at once; apparent air periods.

70. Glass fog chamber—Penetration.—It seemed necessary to repeat the work on the penetration of radium radiations as well as the experiments on their effect from a distance with the aid of the cylindrical fog chamber of glass; for a vessel of this type may be made rigorously tight, whereas entire freedom from leakage is often difficult to maintain in the plate-glass apparatus. From what has been stated, leaks of any kind, even if small, are favorable to the occurrence of water nuclei and therefore to periodicity. The data are given in table 56 and curves 88.



FIGS. 88–90.—Illustrating table 56.

TABLE 56.—Penetration of radium radiation. Cylindrical glass fog chamber without casket. $\delta p = 22$ cm. Lead tube, 30 cm. or 60 cm. long. Walls, 0.5 cm. thick.

Part.	Remarks.	Distance.	s_1.	s_2.	s_3.	$N_1 \times 10^{-3}$	$N_2 \times 10^{-3}$	$N_3 \times 10^{-3}$
I.	Radium in Al tube..............	0	4.4	3.0	4.1	44.0	13.2	35.0
	Radium in 1 Pb tube, capped..	0	3.4	3.7	3.7	20.4	27.6	27.6
	Radium in 1 Pb tube, cap off..	0	2.7	2.7	3.7	10.4	9.8	27.6
	Radium in 1 Pb tube, cap on..	0	3.7	3.1	3.9	27.6	14.6	30.0
	Radium in 1 Pb tube, cap off..	0	3.3	3.9	.....	18.6	30.0	......
	Radium at ∞*....................	∞	0	0	.....	0	0	......
	Radium in 2 Pb tubes, cap off..	0	3.4	3.3	3.2	20.4	18.6	16.6
	Radium in 2 Pb tubes, cap on..	0	3.3	3.3	3.2	18.6	18.6	16.6
II.	Radium in Al tube..............	0	3.5	3.2	3.7	22.6	16.6	27.6
		10	2.9	2.8	2.9	11.8	11.0	11.8
		0	3.6	2.4	3.6	25.0	6.6	25.0
		10	3.1	3.1	3.2	14.6	14.6	16.6
		30	2.3	2.4	3.0	5.4	6.6	13.2
		100	1.9	1.9	1.9	3.6	3.6	3.6
		200	1.5	1.5	1.5	2.8	2.8	2.8
		50	2.1	2.2	2.2	4.4	5.0	5.0
		†0	4.7	2.7	3.9	56.0	27.6	30.0
	Radium at ∞......................	......	0	0	0	0	0	0

* Air effect frequently tested. † Flat against chamber.

In the first part of table 56 the radiation passes through thick lead tubes, P, placed parallel to and contiguous with the end of fog chamber A, as shown in fig. 88. There is no observable effect due to the cap, nor to the length of the lead tubes, whence it follows that the rays producing the nuclei actually pass through the heavy walls of lead. If mean values be taken for the periodic data, the results are (curve 89):

Radium in thin sealed aluminum tube, $N = 27{,}000$
Radium in lead tube, walls 0.5 cm., $N = 23{,}000$
walls 1.0 cm., $N = 18{,}000$

or 85 per cent and 67 per cent pass, respectively, through the walls of lead 0.5 cm. and 1 cm. thick. The important result follows here, as above, that the extremely penetrating rays are responsible for the observed nucleation.

71. Radiation from a distance.—It is surprising to compare with the penetrating effect of the radiation the relatively marked diminution of its intensity with distance. Indeed, if distances be reckoned from the line of sight (supposing this to be justified) about 10 cm. from the end of the chamber, the mean data are (curve 90):

$D =$	10	20	40	60	110	210 cm.
$N \times 10^{-3} =$	30	13	8	5	3	2
$ND \times 10^{-4} =$	30	26	32	30	33	42

where the decrease is about inversely as the distance, except at long distances, when the data become uncertain. All this is in strong contrast with the X-ray effect, where the removal of the bulb to a distance is so much less significant than the presence of a dense screen in the path of the rays.

72. Distribution of nucleation along the axis within the fog chamber.—This makes a final anomalous feature of the results. Whereas the nucleating effect falls off nearly 25 per cent when the radium is placed axially at a distance of 40 cm. from the end of the fog chamber, outside of it the size of the coronas is about the same from end to end of the inner length of about 40 cm., no matter what may be the position of the radium outside.* It will be remembered that the decay and generation of the nucleus is so nearly instantaneous, that convection or like discrepancy is quite out of the question. These observations are difficult because of the short length of the chamber and the rapid subsidence; but so far as they have gone, there seems to be an entire contrast between the behavior of the radiation outside of the chamber and the behavior inside of it, the aluminum tube being in every case outside of the chamber and axial in position.

SUMMARY AND CONCLUSIONS.

73. General remarks.—The results of this chapter relate to fleeting nuclei (ions), to persistent nuclei, to fog limits, to persistence of fleeting nuclei or ions on solution, to the alternations of large and small numbers of efficient nuclei in successive identical exhaustions, to the secondary generation of nuclei after intense X-radiation, to the distribution of radiation in the space surrounding the X-ray tube in contrast with the corresponding case of the sealed tube with weak radium, to the nucleation produced by the gamma rays and its distribution within the fog chamber, etc. They are thus of considerable importance in their bearing on the present research, and will therefore be advantageously summarized at the end of this memoir, in Chapter VI, section 91 *et seq.*, in connection with other relevant matter.

* The statement in the text needs correction. My recent experiments have shown that there is an axial gradation of the number of fleeting nuclei within the fog chamber. This gradation becomes very marked when the fog chamber consists of parts which are unequally strong secondary radiators. Discussion will be made elsewhere.

PLATE I.

Station of U. S. Weather Bureau at Block Island, illustrating barren nature of Island.

CHAPTER IV.

THE NUCLEATION OF THE ATMOSPHERE AT BLOCK ISLAND.

BY ROBINSON PIERCE, JR.

74. Introductory.—The present series of experiments, during the winter of 1904–5, was undertaken with a view to comparing the nucleation in pure country air with the results obtained at the same time in Providence.* After a consideration of several places, Block Island, R. I., was chosen as a station, on account of its location, in the ocean (see fig. 94) 10 miles south of Point Judith, and the freedom from smoke and other refuse commonly found in the air of cities. At the same time, the two stations are, in other respects, meteorologically nearly identical. Through the courtesy of Prof. Willis L. Moore, chief of the United States Weather Bureau, the office of the Bureau on the island was placed at our disposal, and the apparatus was duly installed there during the latter part of November. The chief occupations on Block Island are fishing and farming, and the only smoke is that from dwellings, which are to a great extent scattered. As the high readings usually occurred with north to west winds, the situation of the Weather Bureau building northwest of the village gave complete freedom from all such local influences.

I have here to express my thanks to Mr. W. L. Day, the local observer, for his assistance in many ways during my stay at the island. Mr. Day took the observations at various times, and the results from March 10–14 and April 19–25 are his.

75. Apparatus.—The apparatus used was similar to that employed by Professor Barus,† and the two were operated side by side for some time previous to leaving Providence, with results well in accord. A brass cylindrical trough was substituted for the wooden one late in December and a few minor changes were made from time to time, all of which were tested to make sure that they did not affect the readings of the instrument.

* C. Barus: Smithsonian Contributions, Vol. xxxiv, 1905, Chap. IX; also Chap. V of the present memoir.

† Barus: Loc. cit.

In the following table the weather is given in terms of F fair, Fc partly cloudy, C cloudy, R rain, Sn snow, S sun; the wind directions, in points of the compass. The coronal angular diameter, ϕ, is such that $30 \times 2 \sin \phi/2 = s$, or nearly $\phi = s/30$, when the eye at the goniometer and the source of light were at distances 85 cm. and 250 cm., respectively, from the fog chamber between them. N is not corrected for the temperature (°C.) of the apparatus, this being added in the next table. The reduction from s to N is made as in Barus's memoir (Smithsonian Contributions, 1905, Vol. XXXIV), and the measurement of s made to the outer edge of the red ring, coinciding with the inner edge of the blue or green rings. Exhaustions were made to a pressure difference of $\delta p = 17$ cm.

TABLE 57.—Successive observations of the nucleation (N in thousands per cubic centimeter) of the atmosphere at Block Island.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1904.				°C	°F				
Nov. 26	3.5	F′	NW	18.0	38	—	....	—	Leaky trough.
	3.8	F′	NW	18.0	38	—	....	—	Do.
	4.4	F	NW	15.0	38	3.1	....	10.2	New trough.
	4.6	F	NW	14.5	37	2.8	....	7.3	
27	9.8	C	No wind	17.8	34	2.2	cor	3.3	
	9.9	C	No wind	18.0	34	2.7	cor	6.6	
	12.7	C Sn	SW	17.6	31	3.0	cor	9.3	
	12.8	C Sn	SW	17.7	31	3.0	cor	9.3	
	2.5	C′	NW	18.0	32	2.2	cor	3.3	
	4.2	C′	NW	17.6	32	4.3	w b p	28.0	Possibly some warm air
	5.0	C′	NW	18.3	32	2.3	cor	4.0	
28	9.5	F	NW	15.0	25	2.6	cor	5.9	
	10.4	F	NW	14.8	24	2.6	cor	5.9	
	11.8	F	NW	15.0	23	3.1	cor	10.2	
	2.5	F	NW	14.8	26	3.3	w b cor	12.5	
	3.7	F	NW	15.0	26	3.2	cor	11.3	
	5.0	F	NW	15.0	25	3.1	cor	10.2	
29	9.5	C	SW	15.2	37	2.2	cor	3.3	
	12.0	C	S	16.2	—	3.4	w b cor	13.8	
	1.5	C	S	16.4	—	3.6	w b cor	16.2	
	3.1	C	S	16.7	—	2.6	cor	5.9	
	4.2	C	S	17.0	—	2.3	cor	4.0	
	5.5	C	S	17.0	50	2.3	cor	4.0	Repeated same.
30	9.3	C	SW	16.6	47	1.4	cor	1.4	Rain at night.
	10.9	C	SW	16.9	49	1.3	cor	1.3	Thick, almost foggy.
	12.0	C	SW	17.8	50	2.0	cor	2.5	
	1.5	C	SW	17.6	49	1.8	cor	1.9	
	3.1	—	—	17.3	48	1.7	cor	1.8	
	4.1	C′	SW	17.0	48	2.0	cor	2.5	
	5.3	C′	SW	16.8	47	1.8	cor	1.9	
Dec. 1	8.4	C′	W	18.8	34	2.2	cor	1.3	
	10.8	C′	W	18.5	36	1.7	cor	1.8	
	11.2	C′	W	18.5	36	1.9	cor	2.2	
	12.1	C′	W	18.5	36	2.1	cor	2.7	
	2.0	C′	W	18.2	37	2.2	cor	3.3	
	3.5	C′	W	18.2	37	2.2	cor	3.3	
	5.6	C′	W	18.3	36	2.0	cor	2.5	
2	8.7	C	NW	16.3	33	1.4	cor	1.4	Very faint; influx tube shortened from 34 to 14 feet.
	9.1	C	NW	16.3	33	1.4	cor	1.4	
	10.8	C	NW	16.6	32	1.9	cor	2.2	
	12.2	C	NW	16.8	32	1.9	cor	2.2	

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture *s*.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1904.				°C	°F				
Dec. 2	1.8	C	NW	17.0	32	2.8	cor	7.3	
	3.8	C′	NW	16.9	32	2.2	cor	3.3	
	5.3	C′	NW	16.9	31	2.4	cor	4.6	
3	8.6	C	NE	15.5	27	1.8	cor	1.9	
	10.3	C	NE	15.6	28	2.0	cor	2.5	
	12.4	C Sn	NE	16.1	28	1.6	cor	1.6	
	2.9	C Sn	NE	16.1	29	2.2	cor	3.3	
	4.4	C	NE	15.3	29	2.9	cor	8.3	
	5.4	C	NE	15.5	30	2.7	cor	6.6	
4	9.1	C′	NW	15.6	25	1.7	cor	1.8	
	12.4	C	NW	15.6	27	2.9	cor	8.3	
	2.7	C	W	16.1	30	3.1	cor	10.2	
	6.7	C	W	16.2	30	2.3	cor	4.0	
5	8.4	F	NE	15.0	27	1.5	cor	1.5	
	10.5	C	E	15.6	31	1.6	....	1.6	
	12.3	C	SE	16.3	33	1.6	....	1.6	
	2.1	C	SE	16.5	34	1.1	....	1.1	
	3.7	Sn	S	16.8	33	2.1	....	2.7	
	5.2	Sn	S	16.4	33	2.0	....	2.5	Snow fell, 3.5 inches.
6	8.9	F	NW	14.5	30	1.6	....	1.6	
	10.7	F	NW	14.9	32	2.9	....	8.3	
	12.3	F	NW	15.3	33	2.6	....	5.9	
	1.9	F	NW	15.8	32	3.0	w b p	9.3	
	3.4	F	NW	16.1	32	2.9	....	8.3	
	5.6	F	NW	16.5	31	2.7	....	6.6	
7	9.2	C	SW	16.5	36	1.5	cor	1.5	
	10.5	C	SW	16.0	36	2.3	....	4.0	
	12.5	C′	SW	16.1	36	2.5	....	5.2	
	2.7	C	SW	16.1	37	2.7	....	6.6	
	4.0	C	W	16.5	37	3.0	....	9.3	
	5.2	C	W	16.8	38	2.6	....	5.9	
8	9.0	C Sn	SW	16.6	31	2.5	....	5.2	
	10.5	Sn	SW	17.0	33	2.5	....	5.2	
	12.3	Sn	W	17.4	35	2.6	....	5.9	
	1.9	Sn	W	17.5	35	2.9	....	8.3	
	3.5	Sn	W	17.6	37	2.0	....	2.5	
	5.3	Sn	W	17.5	35	2.1	....	2.7	
9	8.6	F	NW	14.1	23	2.1	....	2.7	
	9.9	F	NW	14.0	24	2.4	....	4.6	
	11.3	F	NW	13.9	24	2.5	....	5.2	
	12.7	F	NW	14.0	26	3.0	....	9.3	
	2.6	F	NW	13.3	25	3.7	....	17.5	
	4.3	F	NW	14.0	24	3.7	....	17.5	
	5.4	F	NW	14.4	24	3.0	....	9.3	
10	8.7	C	NE	13.4	18	—	....	—	Too small to measure.
	12.2	C	N	13.4	17	1.9	....	2.2	
	1.8	C	N	12.2	18	2.8	....	7.3	Hand pump.
	5.3	Sn	N	11.0	18	2.0	....	2.5	
11	10.0	F	NW	10.0	15	—	....	—	Oil lamp.
	11.6	F	NW	10.6	16	4.7	....	37.2	Hand pump.
	12.8	F	NW	11.0	17	3.9	....	20.5	Do.
	3.1	F	NW	10.8	20	3.6	....	16.2	Do.
	6.8	F	NW	11.0	22	2.8	....	7.3	Do.
12	9.1	C	SE	13.6	31	—	....	—	Too small to measure.
	10.5	C	SE	14.6	32	—	....	—	Do.
	12.0	C	SE	14.9	33	1.3	....	1.3	
	3.4	C Sn	NE	14.6	31	—	....	—	Do.
	4.8	Sn	NE	14.8	31	1.9	....	2.2	
13	9.2	Sn	N	11.6	24	3.0	....	9.3	
	9.4	Sn	N	11.8	24	2.7	....	6.6	
	10.7	Sn	N	11.9	24	2.6	....	5.9	
	12.1	Sn	N	12.0	24	2.9	....	8.3	
	2.7	C	N	12.0	26	2.9	....	8.3	
	4.8	C	NW	11.9	28	3.5	w p cor	15.0	
14	9.0	F	NW	12.0	15	3.7	w p cor	17.5	
	10.8	F	NW	12.0	16	4.7	w | b | p	37.2	
	12.3	F	NW	12.3	17	4.7	w P cor	37.2	
	2.5	F	NW	12.1	17	4.9	w | b | p	41.7	
	4.6	F	NW	12.7	17	3.8	w P cor	19.0	
	5.3	F	NW	12.5	19	3.7	w P cor	17.5	

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1904.				°C	°F				
Dec. 14	9.3	F	NW	12.5	18	3.2	w P cor	11.3	
	11.3	F	NW	12.2	20	2.6	cor	5.9	
15	8.9	C	NE	12.0	28	3.0	cor	9.3	
	11.0	C	NE	13.0	28	2.9	....	8.3	
	12.2	C	NE	12.9	30	2.5	....	5.2	
	1.9	C	NE	13.4	31	2.9	....	8.3	
	5.5	C	NE	13.5	30	4.3	w p g	23.0	Snow at night.
16	9.6	C	N	14.6	29	0.0	....	.0	
	12.3	C	N	14.4	31	2.3	....	4.0	
	3.2	F	NW	15.3	32	2.7	....	6.6	
	4.5	F	NW	15.5	32	2.8	....	7.3	
	5.4	F	NW	15.4	31	3.2	....	11.3	
	7.1	F	NW	15.9	31	2.7	....	6.6	
	9.2	F	NW	15.9	30	2.4	....	4.6	
	10.6	F	NW	16.3	29	2.9	....	8.3	
17	9.0	F′	NW	13.9	25	2.4	....	4.6	
	10.8	F	NW	13.8	29	3.0	....	9.3	
	12.1	F	NW	15.5	29	3.3	....	12.5	
	3.3	C	NW	16.6	29	3.4	....	13.8	
	4.2	C	N	16.9	29	2.5	....	5.2	
	5.3	C	N	16.8	29	2.7	....	6.6	
18	10.7	C′	NW	14.0	29	2.7	....	6.6	Blizzard at night.
	12.3	C′	NW	14.0	29	3.7	w br g	17.5	
	1.1	C′	NW	14.4	30	3.4	w rp g	13.8	
19	9.3	C	S	13.6	35	2.7	....	6.6	
	12.6	C	S	14.0	41	3.1	....	10.2	
	3.4	C	SW	15.6	41	2.1	....	2.7	
	6.0	C	W	16.2	36	2.7	....	6.6	
20	8.7	F	NW	16.3	31	3.0	....	9.3	
	10.7	F	NW	16.6	32	3.1	....	10.2	
	12.0	F	NW	17.0	32	3.7	....	17.5	
	2.1	F	NW	17.6	32	2.9	....	8.3	
	3.6	F	NW	17.8	32	3.7	....	17.5	
	6.0	C′	W	18.0	32	3.0	....	9.3	
21	9.1	C	W	15.0	31	2.3	....	4.0	
	10.5	C′	NW	15.3	31	3.2	....	11.3	
	12.2	C′	NW	15.6	31	2.8	....	7.3	
	1.6	F	NW	15.1	30	2.5	....	5.2	
	4.6	F	NW	15.3	26	3.7	....	17.5	
	5.6	F	NW	15.2	25	3.4	....	13.8	
22	8.9	F	SW	13.7	27	2.4	....	4.6	
30	3.5	F	SW	18.0	30	3.1	....	10.2	Snow in morning.
	5.7	F	SW	18.0	30	2.8	....	7.3	Brass trough.
31	9.4	F	SW	17.8	38	1.9	....	2.2	
	10.8	F	SW	18.8	39	2.4	....	4.6	
	12.1	F	SW	18.8	41	2.3	....	4.0	
	3.3	F	SW	19.4	41	2.2	....	3.3	
	5.8	F	SW	19.8	40	2.4	....	4.6	
1905.									
Jan. 1	10.5	F	W	18.6	40	1.7	....	1.8	
	12.5	F	W	19.3	43	2.7	....	6.6	
	2.6	F	W	19.8	45	2.2	....	3.3	
	6.7	F	W	20.0	40	1.9	....	8.3	
2	9.4	C′	SW	18.4	44	0.0	....	0.0	
	10.6	C′	SW	20.8	43	2.3	....	4.0	
	12.2	C	SW	20.4	44	2.1	....	2.7	
	2.4	C	SW	20.0	43	1.8	....	1.9	
	4.1	C	SW	19.0	42	1.8	....	1.9	
	5.4	C	SW	18.9	42	1.8	....	1.9	
3	8.6	R	NE	17.4	38	0.0	....	0.0	
	10.0	R	NE	17.8	38	0.0	....	0.0	
	12.2	R	NE	17.8	37	0.0	....	0.0	
	2.8	R	NE	17.3	35	0.0	....	0.0	
	5.0	R	N	17.5	32	0.0	....	0.0	
4	9.7	Sn	N	11.7	17	2.9	....	8.3	Blizzard, 60 miles.
	11.3	C′	NW	12.0	17	1.9	....	2.2	
	12.3	C	NW	12.4	18	2.8	....	7.3	
	2.8	C′	NW	12.8	19	2.1	....	2.7	
	5.2	F	NW	13.6	17	2.9	....	8.3	
5	9.0	F	SW	12.2	18	2.3	....	4.0	

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1905.				°C	°F				
Jan. 5	10.7	F	W	13.0	21	2.8	....	7.3	
	12.3	F	W	13.2	25	2.8	....	7.3	
	2.1	F	NW	13.5	25	2.8	....	7.3	
	3.6	F	NW	13.8	25	4.3	....	28.0	
	4.9	F	NW	13.9	23	2.9	....	8.3	
	5.8	F	NW	13.9	22	2.0	....	2.5	
6	8.8	Sn	E	13.9	30	0.0	....	0.0	
	10.1	Sn	E	14.2	32	0.8	....	.8	
	12.3	Sn	E	14.7	34	1.0	....	1.0	
	3.3	R	E	15.4	36	9.0	....	.9	
	5.9	C	E	15.8	37	1.0	....	1.0	Rain at night.
7	9.7	C	SE	18.5	49	0.8	....	.8	
	11.0	C	SE	19.0	50	1.3	....	1.3	
	12.5	F′	SW	19.5	48	1.5	....	1.5	
	3.5	F	SW	20.0	44	1.7	....	1.8	
	5.9	F	SW	19.7	42	1.8	....	1.9	
8	8.0	F	W	14.4	31	1.6	....	1.6	
	1.5	F	W	17.6	33	2.9	....	8.3	
	3.4	F′	W	16.9	33	2.3	....	4.0	
	7.6	F	W	16.9	31	2.0	....	2.5	
9	8.8	F	NW	15.5	28	1.8	....	1.9	
	10.7	F	NW	15.7	29	2.7	....	6.6	
	12.2	F	NW	16.0	30	2.6	....	5.9	
	1.9	F	NW	16.5	31	2.2	....	3.3	
	3.8	F	NW	16.1	31	2.2	....	3.3	
	5.6	C′	NW	16.1	31	1.8	....	1.9	
10	8.7	C	SW	17.2	36	1.5	....	1.5	
	10.6	C′	W	17.4	36	2.0	....	2.5	
	12.3	C′	W	17.4	37	2.4	....	4.6	
	2.6	C′	W	17.4	36	2.5	....	5.2	
	4.4	F	W	17.4	34	2.7	....	6.6	
	5.8	C′	W	17.5	32	3.4	....	13.8	
11	9.0	C	NW	13.0	25	1.4	....	1.4	
	10.5	F	NW	15.5	26	2.3	....	4.0	
	12.4	C	N	16.0	27	2.1	....	2.7	
	3.1	C	NE	16.5	29	2.3	....	4.0	
	4.9	C	NE	17.1	29	2.7	....	6.6	
	5.9	C	NE	17.0	29	3.3	....	8.3	
12	8.8	R Fog	SE	13.6	41	2.0	....	2.5	Do.
	10.7	Fog	SW	15.7	46	2.3	....	4.0	
	12.5	Fog R	SW	16.7	47	1.5	....	1.5	
	2.4	R Fog	SW	17.8	46	1.8	....	1.9	
	3.4	R	SW	18.2	44	1.8	....	1.9	
	5.6	R Fog	SW	18.8	40	1.8	....	1.9	
13	9.0	F	NW	16.9	29	1.8	....	1.9	
	11.6	C′	NW	16.2	28	2.6	....	5.9	Hazy.
	3.5	C	N	16.4	29	2.8	....	7.3	
	5.7	C	N	16.4	28	2.8	....	7.3	
14	9.5	F	N	12.7	19	1.7	....	1.8	
	12.7	F	NW	17.0	22	3.0	....	9.3	No cloth in trough from here on.
	3.6	F	NW	14.6	22	2.8	....	7.3	
	5.3	F	NW	14.0	21	2.8	....	7.3	
15	8.4	F	NW	11.5	16	2.2	....	3.3	
	11.0	C′	W	12.1	20	2.5	....	5.2	
	12.8	C′	SW	13.0	21	2.9	....	8.3	
	3.3	C′	W	13.0	23	2.7	....	6.6	
	8.0	F	W	14.0	26	3.3	....	12.5	
16	9.3	F	W	13.7	25	3.6	....	16.2	Cleaned trough.
	3.5	F	W	15.0	28	3.2	....	11.3	
	4.9	F	W	15.0	28	4.5	....	32.4	
	6.0	F	W	15.0	28	3.7	....	17.5	
	8.1	F	W	15.0	27	3.3	....	12.5	
	9.6	F	W	15.0	27	2.9	....	8.3	
17	9.0	F	W	14.7	30	2.5	....	5.2	
	10.6	F	W	15.7	32	3.3	....	12.5	
	12.5	F	W	16.6	34	3.4	....	13.8	
	3.2	F	W	16.4	34	2.8	....	7.3	
	6.0	F	W	14.1	33	2.6	....	5.9	
18	9.0	F	NW	16.3	32	2.2	....	3.3	

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1905.				°C	°F				
Jan. 18	10.5	F	NW	16.4	34	2.7	....	6.6	
	12.0	F	NW	16.5	35	2.9	....	8.3	
	3.0	F	NW	17.2	36	2.5	....	5.2	
	4.6	F	NW	17.5	34	2.7	....	6.6	
	5.8	F	NW	17.4	33	2.6	....	5.9	
19	8.8	F′	SW	16.5	40	1.9	....	2.2	
	11.0	F′	SW	16.9	42	2.5	....	5.2	
	12.4	F	SW	17.0	42	3.1	....	10.2	
	2.4	F′	SW	17.6	39	2.7	....	6.6	
	3.7	F′	SW	17.6	39	2.3	....	4.0	
	6.0	F′	SW	17.5	39	2.2	....	3.3	
20	9.1	C′	NW	17.7	37	1.3	....	1.3	
	11.0	C′	NW	17.8	37	2.5	....	5.2	
	12.5	C′	NW	18.0	40	2.7	....	6.6	
	3.2	F	NW	18.4	39	3.1	....	10.2	
	5.9	F	NW	18.7	36	3.0	....	9.3	
21	9.0	F	NE	14.7	31	1.9	....	2.2	
	12.2	C′	NE	17.7	34	4.2	....	25.8	
	2.5	C	E	16.9	35	3.5	....	15.0	
	5.1	C	SE	16.9	36	3.1	....	10.2	Mist, almost rain.
22	9.0	C	S	18.9	40	1.9	....	2.2	Light rain, almost sunshine.
	12.0	C	NW	19.0	38	2.5	....	5.2	
	1.5	C	NW	19.3	37	2.5	....	5.2	
	4.0	C	NW	19.0	37	2.1	....	2.7	
	7.5	C	NW	18.7	36	1.8	....	1.9	
23	9.0	F	NW	12.4	19	2.8	....	7.3	Cleaned trough.
	12.2	F	NW	14.7	21	4.2	....	25.8	
	3.8	F	NW	14.6	23	3.4	....	13.8	
	6.1	F	NW	14.3	23	3.1	....	10.2	
24	8.8	F	NE	8.5	20	1.8	....	1.9	
	12.2	C′	NE	11.0	23	2.4	....	4.6	
	2.8	C	NE	11.9	27	1.9	....	2.2	
	5.7	C	E	12.8	29	1.4	....	1.4	
25	8.9	Sn	NE	12.0	20	1.9	....	2.2	Blizzard.
	11.8	Sn	NE	10.8	21	2.8	....	7.3	Do.
	1.9	Sn	NE	10.5	22	2.6	....	5.9	Do.
	5.1	Sn	N	10.5	12	2.5	....	5.2	Do.
26	9.0	F	NW	8.6	10	2.4	....	4.6	
	10.8	F	NW	8.6	12	3.0	....	9.3	
	12.6	F′	NW	8.5	14	3.2	....	11.3	
	3.2	F′	NW	8.5	14	3.1	....	10.2	
	5.6	F	NW	8.5	22	3.0	....	9.3	
27	8.8	F	W	10.0	18	2.9	....	8.3	
	12.3	F	W	11.7	22	4.0	....	23.0	
	3.3	F′	SW	12.8	24	3.9	....	20.5	
	5.5	F′	SW	13.0	26	3.3	....	12.5	
28	9.3	Sn	SW	14.6	29	2.8	....	7.3	
	12.0	C	SW	15.4	34	2.9	....	8.3	
	3.1	C′	W	15.6	33	2.1	....	2.7	
	5.7	C′	W	15.6	30	4.1	....	24.0	
29	9.3	F	NW	13.6	19	1.9	....	2.2	
	12.0	F	NW	14.6	21	2.1	....	2.7	
	1.7	F	NW	14.7	24	2.6	....	5.9	
	3.1	F	SW	15.0	24	3.2	....	11.3	
30	9.2	Sn	N	15.0	20	1.9	....	2.2	
	12.3	Sn	NE	14.7	22	2.9	....	8.3	
	3.3	Sn	NE	14.8	24	3.1	....	10.2	
	5.4	C	NE	13.9	23	3.6	....	16.2	
31	8.9	C′	NE	12.7	17	1.4	....	1.4	
	12.3	C	NE	13.5	22	2.6	....	5.9	
	2.8	C′	NE	13.7	23	3.2	....	11.3	
	5.6	C′	NE	13.6	22	3.4	....	13.8	
Feb. 1	9.0	F	NW	14.0	19	2.6	....	5.9	
	12.4	F	NW	15.6	24	4.3	....	28.0	
	3.0	C′	W	15.3	26	3.6	....	16.2	
	5.7	C	SW	15.1	26	3.4	....	13.8	
2	9.0	C′	NW	12.2	22	3.1	....	10.2	Snow at night.
	12.3	C	NW	14.0	22	4.1	....	24.0	
	2.3	C′	NW	13.9	21	4.6	....	34.8	

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1905.				°C	°F				
Feb. 2	5.4	C'	NW	15.0	19	4.6	....	34.8	
3	9.0	C'	NW	10.0	9	3.7	....	17.5	
	10.5	C'	NW	10.0	11	4.8	....	39.5	
	12.2	F	NW	10.0	15	5.1	....	46.0	
	3.0	F	NW	11.6	19	4.7	....	37.2	
	6.2	F	NW	12.9	17	3.7	....	17.5	
4	9.5	F	NW	10.0	10	4.0	....	22.0	
	10.7	F	NW	10.0	12	4.2	....	25.8	
	12.2	F	NW	10.0	14	4.7	....	37.2	
	3.0	F	NW	11.9	16	4.5	....	32.4	
	6.3	F	NW	11.6	16	3.7	....	17.5	
5	8.4	F	N	12.0	14	2.5	....	5.2	
	10.0	F	NE	12.0	18	3.9	....	20.5	
	1.3	F	NE	13.6	24	3.6	....	16.2	
	3.3	F	E	15.3	24	3.0	....	9.3	
	6.3	F	E	15.4	24	3.7	....	17.5	Snow at night.
6	9.4	R	E	13.8	32	0.0	....	0.0	Cleaning apparatus.
	6.0	Fog	NW	17.4	33	2.1	....	2.7	
7	9.3	F	NW	14.7	22	4.2	....	25.8	Mending apparatus.
	3.7	F	NW	14.1	23	4.7	....	37.2	
	6.2	F	NW	13.6	21	3.6	....	16.2	
8	9.2	F	NW	11.4	16	3.9	....	20.5	
	12.5	F	NW	12.6	26	4.0	....	22.0	
	2.6	F	NE	13.6	30	3.6	....	16.2	
	5.7	F	W	14.0	27	4.1	....	24.0	
9	9.3	Sn	E	14.6	30	1.3	....	1.3	Snow at night.
	12.5	R	E	15.5	33	2.0	....	2.5	
	3.3	R	E	13.7	33	0.0	....	0.0	
	5.8	R	E	15.5	33	0.8	....	0.8	
10	9.2	C	W	17.0	32	3.6	....	16.2	
	12.4	C'	SW	18.0	34	4.4	....	30.0	
	3.1	C	W	17.5	34	3.2	....	11.3	
	5.8	F	W	17.5	32	2.7	....	6.6	
11	9.4	F	NW	13.6	21	3.0	....	9.3	
	12.2	F	NW	13.7	23	4.9	....	41.7	
	3.5	F	W	14.1	24	4.3	....	28.0	
	5.8	F	W	14.2	23	3.9	....	20.5	
12	8.5	F	SE	14.3	25	2.7	....	6.6	
	11.5	C	SE	14.8	29	2.9	....	8.3	
	1.0	C	SE	15.7	31	2.5	....	5.2	
	3.0	C	SE	16.0	34	2.7	....	6.6	
	6.4	R	SE	16.4	37	2.7	....	6.6	
13	9.1	C	SW	17.0	35	2.9	....	8.3	Rain at night.
	10.8	R	SW	17.0	36	2.6	....	5.9	
	12.5	R	W	16.4	35	2.7	....	6.6	
	3.2	Sn	NW	16.4	28	2.7	....	6.6	
	5.8	C	NW	15.8	25	2.9	....	8.3	
14	9.4	F	W	12.1	13	4.3	....	28.0	
	12.3	F	W	11.0	15	3.7	....	17.5	
	2.5	F	SW	11.0	16	3.8	....	19.0	
	6.0	F	SW	12.7	17	3.8	....	19.0	
15	9.3	C	E	11.4	24	1.8	....	1.8	
	11.3	C	E	12.7	24	2.2	....	3.3	
	11.8	C	E	12.7	24	2.0	....	2.5	
	3.5	Sn	NW	13.5	24	3.3	....	12.5	
	5.7	C'	NW	14.3	23	3.1	....	10.2	
16	9.4	F	NW	10.0	10	5.9	....	68.0	
	12.2	F	NW	10.0	14	5.1	....	46.0	
	3.3	F	NW	11.5	17	4.8	....	39.5	
	5.9	F	NW	12.6	17	3.9	....	20.5	
17	9.4	C	SW	12.8	32	2.7	....	6.6	
	12.0	C'	SW	13.7	36	2.6	....	5.9	
	2.9	C	SW	15.0	32	2.7	....	6.6	
	5.5	C	SW	15.8	31	2.8	....	7.3	
18	9.2	F	W	13.9	21	3.6	....	16.2	
	12.3	F'	W	13.9	22	4.4	....	30.0	
	3.0	F'	W	14.1	22	3.8	....	19.0	
	6.0	F'	NW	14.0	20	3.6	....	16.2	
19	8.6	F'	NW	11.7	15	2.9	....	8.3	
	12.3	F'	W	12.9	18	3.7	....	20.5	

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1905.				°C	°F				
Feb. 19	3.8	F′	W	13.9	21	4.2	....	25.8	Aspirator hereafter.
	6.5	F′	W	13.8	21	3.6	....	16.2	
20	9.1	C	SW	14.9	33	2.4	....	4.6	
	12.3	Sn	SW	15.4	31	3.1	....	10.2	
	3.0	Sn	SW	15.6	32	3.0	....	9.3	
	5.4	C	SW	17.0	32	3.3	....	12.5	
21	9.2	F	NW	18.2	35	2.9	....	8.3	Rain at night.
	12.0	F	NE	18.3	38	3.2	....	11.3	
	4.3	F	E	18.8	36	1.7	....	1.8	
	6.0	F	E	18.9	35	1.5	....	1.5	
22	9.1	C	NE	17.3	31	1.0	....	1.0	
	11.0	C	NE	17.0	31	1.2	....	1.2	
	12.3	C	NE	16.9	30	1.4	....	1.4	
	3.0	C	NE	16.6	30	0.8	....	0.8	
	6.0	C	NE	16.4	30	0.0	....	0.0	
23	9.3	C′	N	11.7	23	2.6	....	5.9	
	12.0	C′	N	12.6	25	4.5	....	32.4	
	2.2	C′	NE	13.4	29	4.6	....	34.8	
	4.6	F	NE	14.5	32	4.0	....	22.0	
	5.8	F	NE	14.8	31	3.6	....	16.2	
24	8.8	F′	N	14.9	28	2.8	....	4.0	
	12.2	F′	N	15.0	35	3.9	....	20.5	
	3.0	F′	NW	15.8	36	4.6	....	34.8	
	6.0	F′	NW	15.8	35	3.4	....	13.8	
25	8.9	F	NW	17.0	27	2.6	....	5.9	
	12.3	F	W	17.5	32	4.2	....	25.8	
	2.9	F	W	18.0	35	3.4	....	13.8	
	5.8	F	W	18.3	31	3.1	....	10.2	
26	8.7	C	NE	18.2	33	2.4	....	4.6	
	12.1	C	N	17.5	32	2.6	....	5.9	
	3.1	C	NW	18.2	34	3.0	....	9.3	
	6.3	F′	W	18.4	35	3.4	....	13.8	
27	9.1	F	W	14.0	23	3.8	....	19.0	
	12.1	F	W	14.5	25	4.2	....	25.8	
	3.2	F′	W	15.0	25	4.2	....	25.8	
	5.8	F′	W	15.5	26	3.7	....	17.5	
28	9.0	F′	W	15.2	31	3.9	....	20.5	
	12.2	F′	SW	15.4	35	3.0	....	9.3	
	3.3	F′	SW	15.7	34	3.0	....	9.3	
	6.0	F′	W	17.0	32	4.0	....	22.0	
Mar. 1	9.2	F′	NW	15.7	25	5.1	w | b | p	46.0	
	12.0	F′	W	16.3	28	4.1	....	24.0	
	3.1	F	W	17.0	29	4.4	....	30.0	
	6.0	F	W	17.7	28	3.6	....	16.2	
2	9.2	F	W	14.4	20	4.4	....	30.0	
	12.0	F	W	13.0	24	4.0	....	22.0	
	3.1	F	W	12.4	27	4.7	....	37.2	
	6.0	F	W	13.4	28	3.7	....	17.5	
3	9.0	F	NW	15.2	24	4.0	....	22.0	
	12.2	F	NW	15.8	29	4.2	....	25.8	
	3.4	F	W	16.4	31	3.5	....	15.0	
	6.0	F	W	17.0	30	3.8	....	19.0	
4	9.2	C	S	13.2	34	4.0	....	22.0	
	12.2	C	S	15.0	34	3.1	....	10.2	
	3.0	C	{E N}	16.9	37	2.8	....	4.0	
	5.8	C	N	17.4	35	2.2	....	3.3	
5	8.8	F	NW	13.9	19	2.1	....	2.7	
	12.2	F	S	15.0	24	3.5	....	15.0	
	3.5	C	SW	15.8	25	3.2	....	11.3	
	6.2	F	SW	16.0	26	2.9	....	8.3	
6	9.0	F	N	15.5	37	2.8	....	4.0	
	12.3	F	N	16.0	31	3.1	....	10.2	
	3.2	F	W	16.6	33	3.9	....	20.5	
	5.6	F	W	17.1	31	3.7	....	17.5	
7	8.9	C′	S	17.4	34	3.5	....	15.0	
	12.3	C	S	17.6	34	3.1	....	10.2	
	2.8	C	S	18.3	35	2.6	....	5.9	
	6.0	Sn	SE	18.4	33	2.6	....	5.9	
8	9.0	Fog	SW	18.0	35	2.4	....	4.6	Rain at night.

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number, $n \times 10^{-3}$.	Remarks.
1905.				°C	°F				
Mar. 8	11.9	Fog	SW	18.1	35	2.5	....	5.2	
	3.6	Fog	SW	18.1	34	3.0	....	9.3	
	5.7	Fog	SW	18.3	34	2.6	....	5.9	
9	9.0	F	W	19.0	35	3.0	....	9.3	Rain at night.
	12.5	C	SW	18.6	38	2.5	....	5.2	
	3.3	C	SE	17.6	37	2.6	....	5.9	
	5.9	R	SW	17.3	34	2.5	....	5.2	
10	9.0	C	N	18.8	36	2.7	....	6.6	Do.
	12.1	C	NW	19.3	37	2.8	....	7.3	
	3.2	F′	W	19.7	37	2.4	....	4.6	Clearing.
	6.0	F′	W	20.0	34	3.3	....	12.5	
11	9.0	F	NW	15.0	28	3.5	w r g	15.0	
	12.0	F	NW	15.6	30	4.3	w r g	28.0	
	3.1	F	W	16.4	31	4.6	w r p	34.8	
	6.0	F	W	17.0	30	3.9	w r g	20.5	
12	9.0	F′	SW	17.0	35	3.4	....	13.8	
	12.1	C	SW	17.4	37	3.1	....	10.2	
	3.0	C	SW	18.0	36	3.1	....	10.2	
	8.2	F′	SW	18.3	33	2.5	....	5.2	
13	9.1	F′	N	14.7	27	3.1	....	10.2	
	12.1	F	NE	15.8	30	3.6	....	16.2	
	3.2	F	SW	16.6	32	3.6	....	16.2	
	6.1	F	SW	17.0	29	2.9	....	8.3	
14	9.0	F	N	17.4	31	2.9	....	8.3	
	12.1	C′	NE	17.5	34	3.4	w r g	13.8	
	3.2	F	SW	18.2	36	3.5	w r g	15.0	
	5.9	F	NW	18.5	32	3.1	....	10.2	
15	9.3	F	NE	15.5	28	3.4	w rb p	13.8	
	12.4	F	SW	16.8	34	2.9	....	8.3	
	2.9	F	SW	16.8	34	3.3	w b p	12.5	
	6.0	F	SW	18.0	30	3.7	w ro g	17.5	
16	9.3	F	W	17.9	33	3.6	w br b	16.2	Haze.
	12.3	F	SW	18.3	39	3.0	w | b | p	9.3	
	2.6	C	SW	18.8	36	2.4	cor	4.6	
	5.7	C	SW	18.7	36	2.1	cor	2.7	
17	8.8	C	NE	18.5	33	2.9	cor	8.3	
	12.1	F	E	18.6	37	3.1	w | b | p	10.2	
	2.6	F	SE	19.4	39	2.6	cor	5.9	
	6.0	F	S	19.0	33	2.8	cor	7.3	
18	9.0	C′	SW	17.5	42	3.1	cor	10.2	
	12.1	C′	SW	17.5	47	2.5	cor	5.2	
	3.0	C′	SW	18.3	45	2.4	....	4.6	
	6.0	F	SW	18.0	44	2.4	....	4.6	
19	8.8	R	SW	14.8	42	2.2	....	3.3	
	12.1	R	SW	16.2	42	2.6	....	5.9	
	3.6	R	W	18.9	42	3.1	w b p	10.2	
	6.3	Fog	W	18.5	40	2.4	cor	4.6	
20	8.8	R Fog	NE	14.7	34	1.0	cor	1.0	
	12.0	C	NE	15.2	35	1.4	....	1.4	
	3.4	Fog	NE	16.2	34	1.6	....	1.6	
	6.2	C	NE	16.4	33	1.9	....	2.2	
21	9.3	R	NE	16.1	34	1.0	....	1.0	
	12.1	R	NE	15.8	34	1.3	....	1.3	
	2.8	R	NE	15.6	33	1.1	....	1.1	
	5.7	R	NE	15.4	33	1.0	....	1.0	
22	9.0	C	NE	12.0	33	2.9	cor	8.3	
	12.5	C	NE	13.7	35	2.9	w | b | r	8.3	
	3.0	C	NE	14.0	36	2.5	cor	5.2	
	6.0	F	E	15.4	35	2.1	....	2.7	
23	9.0	F	NE	15.0	35	2.6	....	5.9	
	12.0	F	E	16.5	36	1.9	....	2.2	
	3.0	F	SE	17.5	37	1.6	....	1.6	
	5.8	F	SE	16.7	36	2.0	cor	2.5	
24	9.0	C	E	17.0	36	1.4	cor	1.4	
	12.2	Fog	S	18.0	39	1.7	cor	1.8	
	3.0	C	E	18.0	40	1.9	cor	2.2	
	5.9	C	E	18.0	39	1.5	cor	1.5	
25	9.0	Fog	S	20.0	43	1.9	cor	2.2	
	12.3	Fog	SW	20.0	42	2.4	cor	4.6	
	3.0	Fog	SW	20.0	42	2.7	cor	6.6	

TABLE 57.—Successive observations of the nucleation, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temperature of apparatus.	Temperature of atmosphere.	Aperture s.	Corona colors.	Number. $n \times 10^{-3}$.	Remarks.
1905.				°C	°F				
Mar. 25	5.8	R	NW	20.0	40	2.1	cor	2.7	
26	8.9	F	W	20.0	43	3.3	w | b | p	12.5	Rain at night.
	12.0	F	W	20.0	50	3.2	w | b | p	11.3	
	3.1	F	SW	21.0	48	2.6	cor	5.9	
	6.3	F	S	21.0	40	2.7	cor	6.6	
27	9.0	F	SW	19.0	43	1.8	cor	1.9	
	12.3	F′	SW	18.0	48	2.2	cor	3.3	
	3.0	F′	W	19.0	49	2.4	cor	4.6	
	6.1	F	SW	18.0	45	2.5	cor	5.2	
28	9.3	F	W	19.0	47	2.6	cor	5.9	
	12.0	F′	SW	19.0	52	2.6	cor	5.9	
	3.0	F′	SW	19.0	55	2.3	cor	4.0	
	6.0	F	SW	19.0	49	2.0	cor	2.5	
29	9.3	F	E	21.0	43	1.3	cor	1.3	
	12.2	F	E	22.0	44	1.3	cor	1.3	
	3.0	F	E	22.0	43	1.1	cor	1.1	
	6.0	F	E	20.0	40	1.2	cor	1.2	
30	9.0	F Fog	E	19.0	41	1.0	cor	1.0	Fog at night.
	12.0	F′	S	20.0	47	1.2	cor	1.2	
	2.5	F′ Fog	SW	20.0	45	1.2	cor	1.2	
	6.0	F′	SW	19.0	46	1.0	cor	1.0	
31	8.7	F	W	16.0	45	2.3	cor	4.0	Rain at night.
	12.0	F	W	19.0	52	3.1	w | b | P	10.2	
	3.0	F	W	20.0	52	2.5	cor	5.2	
	6.0	F	SW	21.0	49	2.6	cor	5.9	
Apr. 1	9.0	F	NW	18.0	45	2.3	cor	4.0	
	12.0	F	NW	17.0	48	3.6	w br bg	16.2	
	3.0	F	NW	18.0	47	2.8	cor	7.3	
	5.8	F	NW	19.0	45	3.0	w | b | p	9.3	
2	9.2	F	NW	16.0	35	1.9	cor	2.2	
	12.0	F	NW	16.0	40	2.0	cor	2.5	
	2.5	F	NW	17.0	43	2.1	cor	2.7	
	6.1	F	N	18.0	41	2.5	cor	5.2	
3	9.0	F	NW	18.0	38	3.4	w b p	13.8	
	12.0	F	NW	19.0	46	3.6	w ro bg	16.2	
	3.0	C′	W	19.0	51	3.0	w | b | p	9.3	
	6.0	C′	W	18.0	48	3.0	w | b | p	9.3	
4	9.0	C Fog	SE	20.0	41	2.5	cor	5.2	
	12.1	C	SE	20.0	43	2.0	cor	2.5	
	3.0	C	SE	20.0	42	2.3	cor	4.0	
	6.0	C	SE	20.0	42	1.8	cor	1.9	
5	9.0	C Fog	NE	20.0	41	2.1	cor	2.7	Rain and thaw at night.
	12.1	Fog	N	20.0	43	1.9	cor	2.2	
	3.0	Fog	E	19.0	42	2.2	cor	3.3	
	5.9	Fog	NE	18.0	41	2.2	cor	3.3	
6	9.0	C Fog	S	20.0	47	1.6	cor	1.6	Do.
	12.1	Fog	SW	20.0	44	1.9	cor	2.2	
	3.0	C	SW	19.0	42	3.3	w bp	12.5	
	6.0	F	W	18.0	42	1.8	cor	1.9	
7	9.0	F	W	14.0	39	2.3	cor	4.0	Cleaned flue in morning.
	12.0	F′	W	13.0	42	4.9	w b p	41.7	
	12.2	F′	W	13.0	42	5.7	w cr g	61.5	Test in afternoon showed that this did not produce maximum. No steamers in harbor.
	3.0	F′	W	17.0	44	2.9	w | b | p	8.3	
	6.0	F′	W	18.0	40	3.0	w | b | p	9.3	
8	8.6	F′	W	19.0	38	2.7	cor	6.6	
	12.3	F′	W	19.0	43	3.1	w b p	10.2	
	3.1	F′	W	20.0	43	2.9	cor	8.3	
	6.0	F′	W	20.0	40	2.2	cor	3.3	
9	9.3	F	W	18.0	41	2.8	cor	7.3	
	12.0	C′	W	19.0	45	3.0	cor	9.3	
	3.0	C′	SW	19.0	45	2.9	cor	8.3	
	6.3	C′	SW	17.0	41	1.9	cor	2.2	
10	8.5	C′	SW	13.0	46	2.2	cor	3.3	
	12.1	C	SW	16.0	49	2.1	cor	2.7	
	3.0	C′	SW	19.0	51	2.1	cor	2.7	
	6.0	C	SW	20.0	48	1.3	cor	1.3	
11	9.3	R Fog	SW	18.0	—	2.2	cor	3.3	
	12.6	Fog	NE	17.0	—	1.5	cor	1.5	
	4.0	Fog	NE	17.0	—	1.4	cor	1.4	
	6.2	R Fog	NE	16.0	—	1.6	cor	1.6	

76. Observations.—In the data as given in table 57, the first column contains the date and daily average; the second and third, the time in twentieths of a day and hours; the fourth shows the condition of wind and weather, R denoting rain, Sn snow, H haze, S sun, F fair, Fc or F′ or C′ partly cloudy, C cloudy. The fifth column shows the temperature of the instrument in degrees Centigrade, and the sixth, the temperature of the outside air in Fahrenheit degrees. Column 8 shows the aperture of the corona on the given goniometer; 9, the principal colors from the center outward; 10 (from March 29), the relative humidity and vapor pressure; finally, the last column gives the nucleation in thousands of nuclei per cubic centimeter.

It will be noticed that the temperature of the air in the trough varies considerably at times from 20° C., the temperature for which reductions were made. Each reading was later corrected and the results thus obtained plotted, where the correction amounted to more than a thousand. The corrections as a rule were not large, however, and the original curve shows the relative values equally well. The chief effect is a slight reduction of the maxima on cold days.

In the plates of the next chapter (figs. 95–101) the individual observations are plotted with the weather and mean temperature, the nucleation being given in thousands of nuclei per cubic centimeter. The lower curve belongs to Block Island, the upper curve to Providence, as will there be specified.

77. Remarks on the tables (wood fog chamber).—With the beginning of observations at the island, there is a marked drop from the high readings taken in Providence, showing that a large part of the nucleation observed in the latter place is due to local effects. The same variations with meteorological changes are, however, observed, perhaps even more strikingly. Thus one may note the sudden rise in the afternoon of November 27, when the sky cleared and the wind changed to northwest. On the 30th the rain of the preceding night is followed by a minimum, which, owing to cloudy weather, lasts several days. Snow from the east and south on December 5 cuts down the nucleation, which rises again with the clear sky and northwest wind of the 6th (note the midday minimum) and holds during the two cloudy but dry days following. The clear weather and northwest winds of the 9th, 11th, and 14th bring decided maxima, while minima accompany the northeast wind and cloudiness of the 10th, and the snow from the same quarter on the 12th and 13th. Midday minima occur again on the 15th and 16th; the high reading late in the afternoon of the 15th is unusual. The 16th shows the increase of nucleation with clear northwest wind, while the following day (17th) well illustrates the effect of clouds and northeast wind. It is interesting to note that the blizzard and snow produced no further diminution. On the 20th another midday minimum occurs, with a clear west wind all day. The 21st shows the rise due to clearing sky.

78. Remarks on the tables (brass fog chamber).—The observations were interrupted from the 22d to the 29th on account of some needed repairs, and after that date the brass trough replaced the wooden one previously used. With the low nucleations frequently found, a fog chamber rigorously free from leaks is essential.

During January, maxima, usually accompanying clear weather and west to north wind, occur on the 5th, 10th, 16th, 23d, and 27th to 28th; minima due to rain or snow, with wind from the opposite quarter, appear on the 3d, 6th, 12th, 22d, and 24th to 25th. On the 4th, the notched minimum is uncommon, for the weather at the several times of observations is . The 5th shows a high reading, as the wind passes through the northwest, and the 11th a sun and cloud effect. One may notice a curious gradual decrease on the 16th, 17th, and 18th, with continual clear weather and westerly wind. Clouds on the morning of the 20th bring the maximum later in the day, and the next day (21st) shows an unusual maximum, with cloudy sky and northeast wind.

During January and February there is a noticeable tendency to a uniform type of day curve, rising rather steeply from 9 o'clock until noon or later, and falling more gradually during the afternoon and evening. This is what one would expect on sunny days, in view of the fact that nuclei seem to persist for some time in the atmosphere. This curve is quite well shown on the 17th, 18th, and 19th.

In February the maxima are higher, and occur on the 1st to 5th, 7th to 8th, 10th to 11th, 14th, 18th to 19th, 23d to 25th, and 27th to 28th. On the 6th, 9th, 12th to 13th, and 20th we have rain minima, and low readings due to clouds on the 15th, 17th, and 26th. The 8th shows an interesting minimum during a temporary shift of the wind to northeast, and the 13th a depression during the rain in the middle of the day. Clearing weather on the afternoon of the 15th brings a rise of nucleation, which attains an unusual value next day. A quick drop occurs on the 21st when the wind changes to east, and the opposite effect appears on the 26th. Another curious midday minimum may be noticed on the 28th. Throughout the month the minima are very quickly established by clear weather and northwest wind.

In March the maxima are less pronounced; they occur on the 1st to 3d, 11th, 13th to 16th, and 26th. Minima of longer duration than heretofore accompany the rains of 7th to 10th, 19th to 21st, 23d to 25th, and 29th to 31st. One may note the midday minima on the 1st, 2d, and 3d. The 4th shows a reversal of the usual agreement between the wind and nucleation. On the 7th the readings fall during the day as rain sets in. The wind on the 13th, 14th, and 15th changes suddenly, near noon, from northeast to southwest, but no definite corresponding change appears in the nucleation. A fine cloud effect is shown on the 16th when the sky becomes overcast in the afternoon. On the 23d one may note a minimum, as the wind passes through the east to south.

The variations in the nucleation in April are even less marked; low maxima occur on the 1st, 3d, 7th, and 14th to 16th, while minima accompany rain and fog on the 4th to 6th, and 10th to 14th. An unusually low value is obtained on the 2d, with clear northwest wind, and on the 7th is an unaccountable high reading which seems to have no connection with local influences. From the 16th the weather is warm, with considerable fog, and the nucleation runs low, with little variation to the end of the month.

79. Summary and comparisons.—In figures 91 and 92 are shown together the current nucleations (continuous heavy black line), sunshine (continuous light black line), vapor pressure (heavy broken line), temperature (light broken line), and general weather conditions for each day. The nucleation and temperature given is the *average* of the observations taken during the day, as is the vapor pressure after March 28th; before that date the vapor pressure is the mean of the regular morning and evening observations at the station. Both the temperature and vapor pressure are laid off positively downward. The sunshine is the total for the day as recorded by the office sunshine recorder.

The graph as a whole shows a rather marked similarity in the nature of the several curves. In many cases of discrepancies the nucleation appears to show the effect of conflicting causes. On November 29, with no sun, the nucleation persists from the fairly high reading of the day before, although the other curves drop. Warm rain and further increase of vapor pressure on the 30th cut it down, and it ascends very slowly during the cloudy days following. A decrease accompanies the rise in temperature and vapor pressure of December 5, which is quickly reversed by the sunshine and northwest wind of the 6th. The nucleation curve remains nearly level, as does that of the water vapor, during the two cloudy days succeeding. The sunshine of the 9th and 11th gives maxima which themselves rise with the moisture and temperature curves, while all drop on the 12th. The rise on December 13 seems to accompany the sudden fall in tempera-

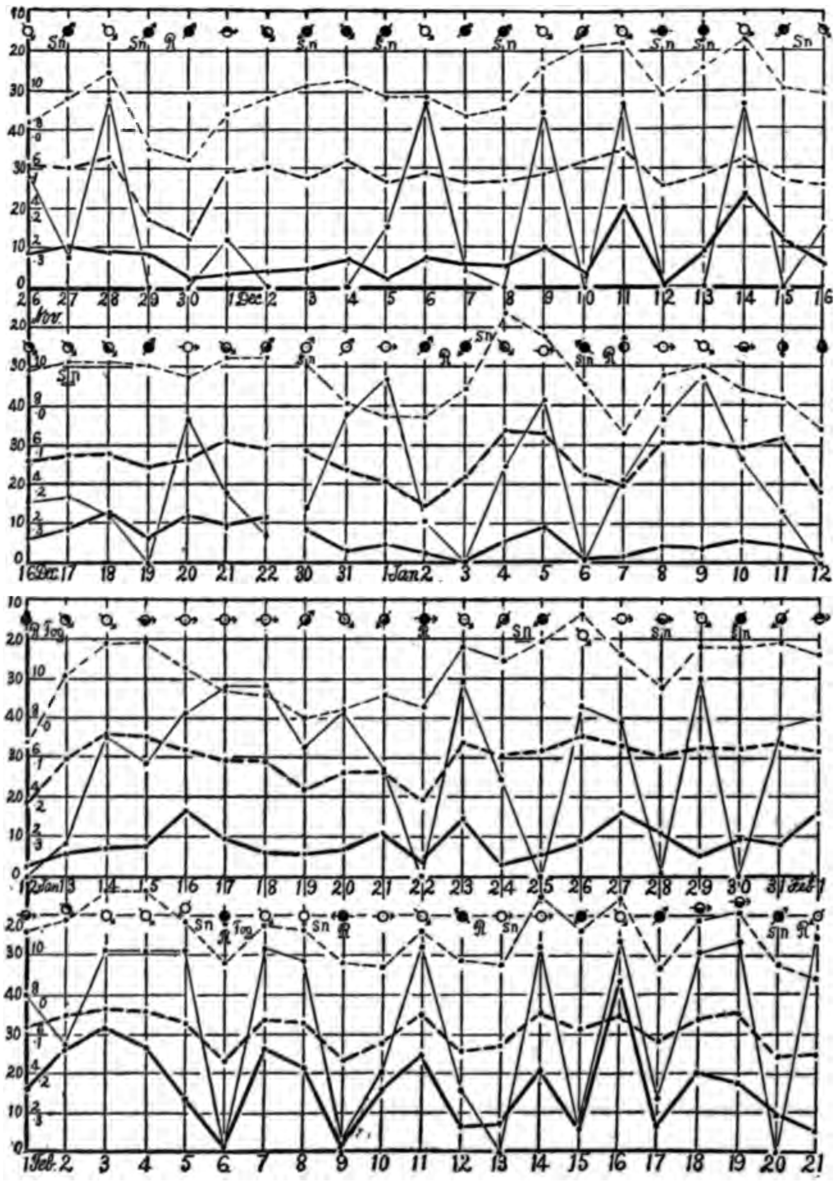


FIG. 91.—Graphs showing current nucleations, etc., November 26 to February 21.

ture and change of wind to north. The maxima of the 18th lags behind the rest, but the readings fall into step next day.

Increase of sunshine on January 1 shows its effect on the nucleation,

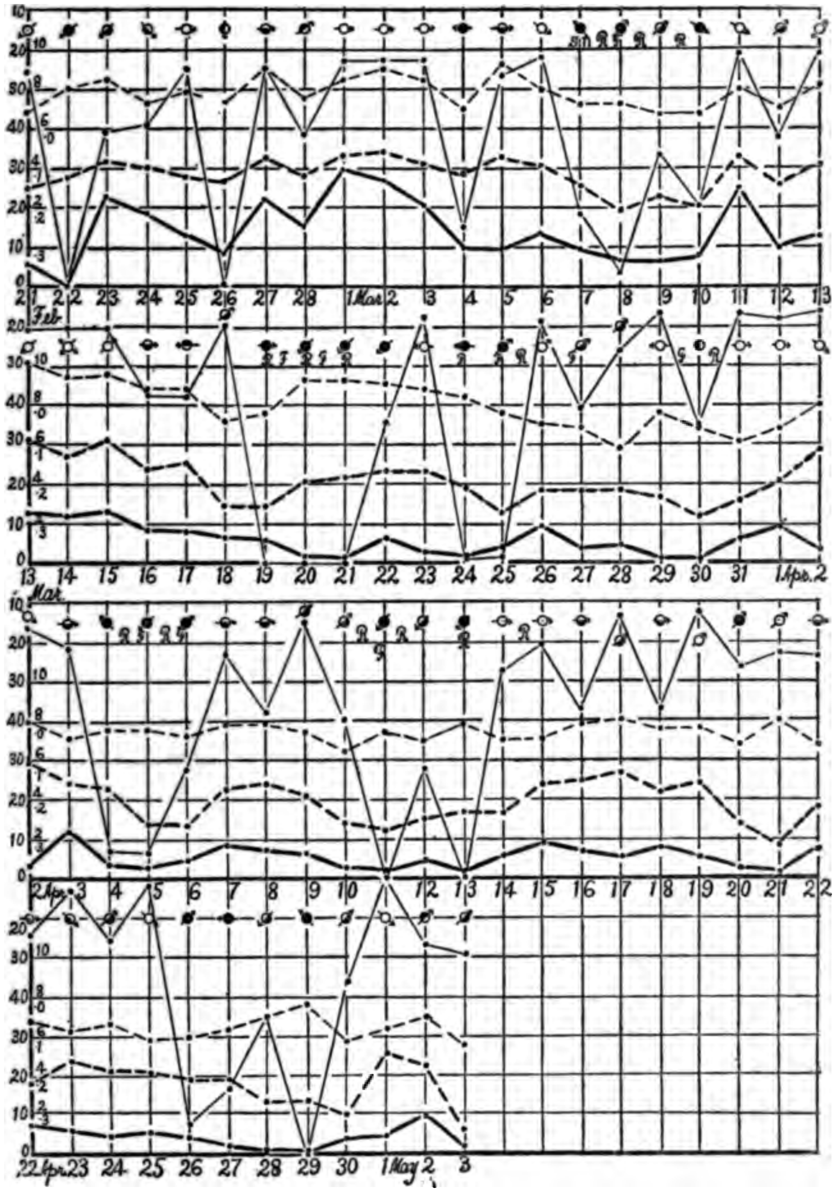


FIG. 92.—Graphs showing current nucleations, etc., February 21 to May 3.

as also on the 5th and 16th. On the 3d the nuclei seem to have been completely wiped out by rain, and we get no more till the sun shines next day. From the 12th to the 16th the nucleation lags behind the other curves in recuperating, and again on the 21st and 27th. As is often the case for low values, the nucleation does not follow the other curves on January 19. During the last days of the month the behavior of the nuclei is quite unusual, although the snow on those days is light and dry.

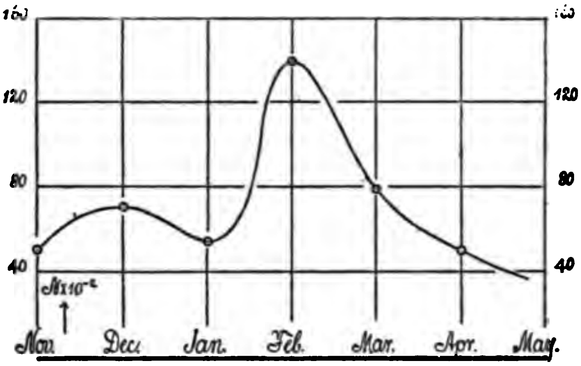


FIG. 93.—Chart showing the average daily nucleations at Block Island, in hundreds per cubic centimeter, from December to May, 1904-5.

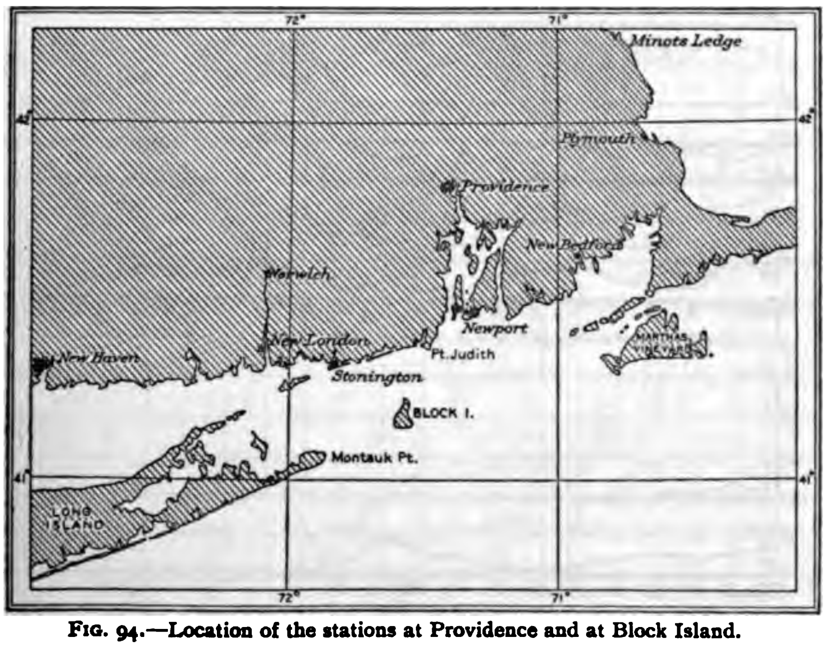


FIG. 94.—Location of the stations at Providence and at Block Island.

The dry, cold weather of February gives a striking series of maxima and minima, with the highest readings of the winter. It is interesting to note the fall in nucleation on the 5th, accompanying rise in temperature and vapor pressure, and east wind, although the sunshine remains the same. Again, on the 13th, following rain in the night, the vapor pressure and nucleation are at their previous value, although there is no sun during that day. On the 20th the nuclei persist through cloud and snow, while on the 22d they disappear entirely with cloudy weather.

The 1st, 2d, and 3d of March, with steady sunshine and wind constantly from the west, show well the agreement between the nucleation and vapor pressure. On the 6th, one notes again the lag of the nucleation in building up, and that the light rain and fog of the succeeding days does not cut down the nucleation entirely. During the rest of March and April there is a considerable amount of water vapor and the temperature runs higher; the nucleation, while it follows the changes in the other curves, remains low, although there is at this period plenty of sunshine. The rains of this time never wash out the nuclei entirely, and readings of several thousand are often obtained in thick fog.

80. Tentative inferences.—Perhaps the most striking result shown by these observations is the variation of the nucleation with change in wind direction. It is very probable that nuclei are brought by the land breeze from towns over which it passes. Our winds from the northeast to southwest, through the east, are pure sea breezes; there is no land in those directions for a great distance, and the readings when such winds occur are usually low. High readings, on the other hand, commonly accompany wind from the other quadrants. Such winds (as seen in fig. 94) pass over towns and cities comparatively near; Newport, R. I., is a little east of north 30 miles distant; the towns on the Connecticut shore lie between northwest and west at distances from 20 miles up; New York, from which one would expect a vast number of nuclei, is a little south of west, distant about 100 miles. When the wind is from this quarter, however, the nucleation is as a rule considerably less than for northwest winds, possibly because the nuclei may not survive so long a journey.

This wind effect, however, must not be overestimated. During the winter months here, clear, cold weather, with small amount of water vapor, occurs quite regularly with northwest winds, and all these conditions usually accompany high nucleation. It is difficult to determine the active factors or their relative influence from a limited series of observations at one station, particularly as the prevailing winds are land winds. Data from places where the northwest wind blows over no cities, and where the northwest wind is warm and the southeast wind dry, would be interesting.

Again, the daily averages of the nucleation appear to vary inversely with those of the temperature and vapor pressure, while in most cases they all vary directly during the day, rising to a maximum near noon. This would seem to suggest an overbalancing effect of the sun in producing nuclei. As regards the relative influence of temperature and vapor pressure, one might look for an increase of nucleation after a sudden fall of temperature, but would hardly expect nuclei to be produced because of continued cold. It seems quite possible, however, that, with a high vapor pressure, there is continual condensation of moisture on the nuclei present, with a persistent tendency to drag them to the earth. The inverse agreement between the nucleation and the relative humidity is even more general, for the latter more often descends to a minimum during the day. The percentage of saturation, moreover, ought to be some index of the condensation taking place, remembering that condensation may be in progress at higher levels when the air at the surface is not saturated, and that, at those planes, small variations of temperature may be producing saturation. The absorption of the sun's rays, if they produce nuclei, would also have some effect, but probably to a less degree.

In the case of sunshine and cloud, likewise, the effect is obscured for sudden changes by variation at the same time in the vapor pressure. The cloud effect is partly the opposite of that attributable to the sun, which has been assumed to produce nuclei throughout the day in the upper atmosphere. Clouds catch these if they come within range, and prevent the formation of others near the surface. Clouds, however, are at the same time apt to be an index of a region denucleated by rain.

The persistence of nuclei is shown in two ways. Readings, usually less than 10,000, are often obtained through several days of cloud, snow, fog, and even light rain. These have either penetrated through the clouds or they have been brought from cities, in which case the land effect here must be small. Persistence, and therefore the supposed cumulative action of the sun, is shown in the day curve, in which the 3 o'clock reading is nearly as high as that at noon, although the sun is then as low as at 9 o'clock. Similarly, the lag of the nucleation in building up after rain, or after a persistent cloud effect, would seem to indicate the cumulative action of the sun.

Taken as a whole, therefore, it seems to me probable that something more than the displacement of a land effect, produced artificially and locally elsewhere, chiefly by combustion, has been observed. In other words, it would be premature to attribute the phenomena as a whole to atmospheric convection.

TABLE 58.—Average daily nucleations of the atmosphere at Block Island, 1904–5.

Date.	$N\times10^{-3}$.	Date.	$N\times10^{-3}$.	Date.	$N\times10^{-3}$.	Date.	$N\times10^{-3}$.
1904.		1905.		1905.		1905.	
Nov. 21	......	Jan. 5	8.1	Feb. 14	17.4	Mar. 26	9.1
22	......	6	.7	15	5.3	27	3.7
23	......	7	1.5	16	35.5	28	4.5
24	......	8	3.9	17	5.9	29	1.3
25	......	9	3.5	18	17.9	30	1.1
26	7.9	10	5.4	19	15.4	31	6.2
27	9.5	11	4.2	20	8.4	Apr. 1	8.8
28	8.6	12	2.1	21	5.5	2	3.0
29	7.3	13	5.2	22	1.8	3	11.8
30	1.8	14	5.8	23	19.4	4	3.4
Dec. 1	2.6	15	6.2	24	16.7	5	2.8
2	3.3	16	15.0	25	13.3	6	4.4
3	3.7	17	8.3	26	7.8	7	16.2
4	5.6	18	5.6	27	19.7	8	7.0
5	1.7	19	5.0	28	14.0	9	6.6
6	6.1	20	6.3	Mar. 1	27.0	10	2.3
7	5.1	21	12.6	2	22.9	11	1.8
8	4.7	22	3.4	3	18.9	12	4.4
9	8.3	23	12.7	4	8.7	13	1.4
10	2.5	24	2.1	5	8.5	14	5.7
11	16.7	25	4.2	6	12.2	15	7.8
12	0.6	26	6.9	7	8.8	16	5.9
13	7.5	27	13.4	8	6.0	17	5.1
14	19.7	28	9.7	9	6.2	18	8.0
15	10.1	29	5.0	10	7.7	19	5.4
16	5.5	30	8.2	11	22.7	20	2.2
17	8.0	31	7.1	12	9.4	21	1.4
18	11.1	Feb. 1	14.5	13	11.8	22	6.3
19	5.8	2	22.9	14	11.4	23	6.1
20	11.5	3	21.9	15	12.3	24	4.5
21	8.9	4	22.0	16	7.9	25	5.6
22	10.1	5	12.0	17	7.8	26	4.3
30	8.4	6	1.2	18	5.9	27	2.2
31	3.7	7	23.4	19	5.7	28	1.4
		8	17.8	20	1.4	29	1.3
1905.		9	1.0	21	1.0	30	4.2
Jan. 1	5.0	10	15.3	22	5.3	May 1	8.6
2	2.6	11	21.9	23	2.8	2	2.1
3	0	12	6.1	24	1.6	3	4.5
4	4.9	13	6.6	25	4.0		

81. Average daily nucleations at Block Island.—The mean variations of the nucleation at Block Island from day to day are given in table 58, and they have been already charted in figures 91 and 92. The data are constructed for rapid inspection in figure 102, of Chapter V (lower curve). The initial (high) observations marked with a circle were made with the same apparatus in Providence. The curve as a whole shows two well-defined undulations, one extending from December into the beginning of January and the other from this epoch to the beginning of April. After this the data are scattering. Further discussion will be appropriately given in connection with the corresponding data found at Providence and detailed in the next chapter.

82. Average monthly nucleations at Block Island.—Table 59, below, contains the monthly average of the number of nuclei in the atmosphere of Block Island in thousands per cubic centimeter. The data are reproduced in figure 93. The curve contains definite indications of a maximum in December practically coinciding with those found in the two preceding years in Providence, as suggested by the dotted line. After January, however, the enormous increment of nucleation which characterizes the February observations appears. This is the feature of the present results, and the effects continue with general moderations during March and April; for the nucleation of March actually exceeds that of December, while April is not much below January, showing, therefore, that very unusual conditions prevail in the atmosphere.

To interpret this curve, *i. e.*, to discriminate between terrestrial and cosmical interferences with the atmosphere, it will be necessary to compare it with the corresponding monthly distribution of the meteorological constants of the atmosphere. This will be appropriately done in Chapter V, section 5, in connection with the other data there given.

TABLE 59.—Average monthly nucleations at Block Island, 1904–5.

		$N \times 10^{-3}$.
* November,	1904	< 7.0
December,	1904	7.1
January,	1905	5.4
February,	1905	13.9
March,	1905	7.9
April,	1905	5.0
† May,	1905	< 5.0

* November 21–30, only. Average datum therefore too high.

† May 1–3, only. Average datum therefore much too high.

CHAPTER V.

THE COTEMPORANEOUS NUCLEATIONS OF THE ATMOSPHERE AT PROVIDENCE AND AT BLOCK ISLAND.

83. Introductory.—In the preceding chapter, Mr. R. Pierce, jr., has given an account of his observations of the nucleation of the atmosphere at Block Island. I purpose in this place to give the corresponding data for Providence. The two stations lie nearly enough together to have about the same general meteorological elements, while the conditions as to nucleation may be totally different. Block Island is surrounded by a body of water the least radius of which, measured from the center of the island, is nearly 20 kilometers. It lies about 70 kilometers from Providence in a direction about 10° west of south. Fully one-half of Block Island fronts the ocean, as is seen in figure 94, Chapter IV. The atmosphere at the former place should be relatively free from pollutions due to the habitation of man, while the reverse is naturally true of the latter. It is unfortunate that in both cases the prevailing winds are land winds, at least from a distance, and in discussing observations it must be borne in mind that the wind bearing is not indiscriminately in all directions. I shall at the same time avail myself of the series of observations, extending over two years, contained in my report* to the Smithsonian Institution, which, with the present series, complete a three years' period.

84. Observations.—These are taken with less frequency than in the former paper (loc. cit.), but are otherwise on the same plan. The entries of the table are at once intelligible. The time of day is in hours and tenths of an hour. Weather variations are noted from cloudy (C), partly cloudy (FC) to fair (F). The temperature of the apparatus is given in degrees Centigrade; those of the atmosphere in degrees Fahrenheit. The coronal diameter, is shown under s, which is the chord of a radius of 30 cm., when the eye at the goniometer and the source of light are 85 cm. and 250 cm., respectively, from the fog chamber. The number of nuclei per cubic centimeter, given under n, has not been corrected for temperature, as the difference for the present purposes is unessential.

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*Smithsonian Report, vol. XXXIV, 1905.

TABLE 60.—Number of nuclei (n) per cubic centimeter in the atmosphere of Providence, R. I., from November 1, 1904, to May 1, 1905.

[Weather: C cloudy, CF partly cloudy F fair. Coronal colors (r red, b blue, p purple, w white, o orange, y yellow, g green, br brown) are given from the center outward. An accent denotes an approach to the color (y' yellowish); a perpendicular line, a thin ring of indeterminable color If ϕ is the angular diameter of the corona measured to the outside of the first red ring, $2 \sin \phi/2$ $s/30$.]

Date.	Time	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	s.	Corona colors.	n. Number.	Remarks.
1904.	*Hour.*			°C	°F	*cm.*			
Nov. 1	9.6	F	W	16.1	50	3.2	w | b | p	42,000	
	1.0	C	NW	17.1	54	3.1	w | b | p	38,000	
	4.0	C	N	—	53	3.1	w | b | p	38,000	
2	9.8	F	N	17.1	43	3.1	w o g	38,000	
	4.2	F	S	19.1	48	3.1	w | b | p	38,000	
	5.8	F	....	19.1	45	6.4	w r g	86,000	
3	9.4	C	S	18.1	50	6.1	y' c g	75,000	
	11.9	C	S	19.1	53	5.1	w | b | p	46,000	
	3.1	C	SW	19.1	56	4.8 4.8	cor	39,000	
4	10.4	F	N	19.1	55	4.6	w r g	35,000	
	10.8	F	....	20.1	—	5.1	w | b | p	46,000	
	11.3	F	N	20.1	57	4.7	w o g	37,000	
	12.3	F	....	20.1	57	3.9	cor	21,000	
	4.4	C	NW	20.1	51	3.5	—	15,000	
	6.0	C	....	20.1	47	3.8	—	19,000	
5	10.1	C	N	18.1	44	3.5 3.5	cor	15,000	
	1.0	C	N	19.1	45	4.6	w r g	34,800	
	3.2	C	NE	19.1	42	3.8	w r g	19,000	
	6.1	C	....	21.1	38	4.9	w | b | p	41,700	
6	9.6	C	N	18.1	37	4.3	cor	28,000	
	11.8	F	NW	17.1	43	5.4	wp cor	54,200	
	12.2	F	....	—	44	5.3	w | b | p	50,500	
	6.0	F	....	17.1	42	4.7	w r g	37,200	
7	9.5	C	W	15.1	36	4.8 4.8	g | b | p w r g	39,500	
	12.0	F	....	16.1	—	4.9	g | b | p	41,700	
	4.9	F	....	17.1	39	4.8	w r g	39,500	
8	10.5	F	NW	16.1	42	6.6	w o bg	90,000	
	11.6	F	....	17.1	44	5.8	w c g'	64,500	
9	9.5	C	NW	17.1	37	4.9	w | b | p	41,700	
	11.9	Sn!	....	17.1	36	6.3	y' r g	80,500	Repeated same.
	4.4	C Wet	....	18.1	37	5.5	wp cor	56,200	
	6.0	C	....	18.1	36	5.8	w r g	64,500	
10	9.3	F	NW	17.1	37	6.6	y' or g	90,000	
	11.7	F	N	18.1	43	4.8	w r g	39,500	
	—	F	S	19.1	43	5.5	wp cor	56,200	
11	10.4	C	....	18.1	38	4.8	g' | b | p	39,500	Snow.
	5.5	F	N	20.1	34	6.2	w r g	76,500	
12	9.9	F	W	18.1	42	6.0	w rp g	70,500	
	9.9	F	W	18.1	47	6.0	w rp g	70,500	
	5.3	F	....	20.1	46	6.0	w rp g	70,500	
13	10.0	R	W	18.1	46	4.8	w | b | p |	39,500	
	12.6	R	NE	18.1	44	3.8	cor	19,000	
	5.8	R!	....	18.1	42	2.8	cor	7,300	Gale!
14	9.4	C	NW	17.1	40	5.0	w | b | p	43,800	
	12.3	C'	NW	16.1	43	5.5	wp cor	56,200	
	4.2	C' S	....	17.1	42	7.0	g' b' p'	120,000	Vapor.
	4.8	—	....	—	—	6.1	w r g	73,300	
15	9.3	F	N	17.1	41	4.8	g' b p	39,500	
	12.7	F	NW	19.1	49	5.3	wp cor	50,500	
	1.2	F	....	20.1	50	6.2	w r g	76,500	
16	3.0	F	NW	19.1	51	4.8	w o | g	39,500	
	6.0	F	....	20.1	44	4.9	g | b | p	41,700	
17	9.4	F	N	18.1	28	6.3	w r g	80,500	
	1.2	F	N	19.1	32	6.1	w r g	73,300	
	5.0	F	....	19.1	29	4.8	g | b | p	39,500	
18	9.4	F	N	17.1	25	5.7	w rp g	61,500	
	12.4	F	....	17.1	32	6.0	w r g	70,500	
	6.0	F	....	20.1	32	6.3	w ro g	80,500	
19	9.3	F	NW	—	30	5.8	w rp g	64,500	
	12.5	F	....	19.1	—	5.8 6.0	w rp g	64,500	

TABLE 60.—Number of nuclei (n) per cubic centimeter, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	s.	Corona colors.	n. Number.	Remarks.
1904.	*Hour.*			°C	°F	*cm.*			
Nov. 19	3.3	F	NW	20.1	52	5.7 5.0	w rp g wbr cor	61,500	
	5.2	F	....	21.1	47	5.6	w p g	58,700	
20	9.8	F	No wind	18.1	46	4.9	g' ǀ b ǀ p	41,700	
	1.3	F	W	18.1	58	4.6	w r g	34,800	
	5.6	C	....	18.1	52	5.1	w ǀ b ǀ p	46,000	Haze.
21	9.4	F	W	18.1	52	4.5	w r g	32,400	
	12.3	C'	NW	19.1	51	—	—	—	About the same.
22	9.7	F H	....	19.1	42	5.7	wp cor	61,500	
	1.1	F	S	20.1	46	5.0	w ǀ b ǀ p	43,800	
	6.0	F	....	20.1	42	6.2	w r g	76,500	
23	9.0	F	NW	19.1	45	4.8	g' b p	39,500	
	12.1	F	....	19.1	52	4.8	w o cor	39,500	
	5.8	F	....	19.1	44	4.8	g' b p	39,500	
24	9.6	C	N	18.1	42	4.8	g' b p	39,500	Fog.
	12.0	C	N	18.1	43	5.3	wp cor	50,500	
	7.0	F	....	17.1	41	4.9	w ǀ br ǀ p	41,700	
	9.6	F	....	19.1	36	4.6	w o g	34,800	
25	9.8	F	....	16.1	40	6.7	w o bg	92,500	
	1.6	C'	NW	17.1	42	5.8	wp cor	64,500	
	4.7	C	....	17.1	48	4.6	w r g	34,800	
26	9.6	F	NW	17.1	33	5.6	w rp g'	58,700	
	12.2	F	....	18.1	37	5.6	w rp g'	58,700	
	5.6	F	....	19.1	34	5.7	w rp g'	61,500	
27	9.0	F	N	—	25	5.6	w rp ǀ g'	58,700	
	12.0	C	....	15.1	32	4.3	w r g	28,000	
28	9.7	F	NW	14.1	24	6.3	w o g	80,500	
	12.0	F	....	14.1	27	6.4	w y g	83,500	
	5.0	F	....	15.1	26	5.3	wp cor	50,500	
29	11.3	C	S	14.1	34	7.0	w o bg	120,000	Vapor.
	11.9	C	SW	14.1	38	5.9	w rp g	68,000	
	12.3	C	....	14.1	—	5.9	w rp g	68,000	
	3.7	C	....	16.1	44	5.8	w rp g	64,500	
	5.8	C	....	16.1	48	6.2	w ro g	76,500	Rain at night.
30	9.3	C	W	18.1	—	6.2	w ro g	76,500	
	12.3	C	SW	19.1	53	4.8	g b p	39,500	
	6.0	C	....	20.1	46	5.4	wp cor	54,200	
Dec. 1	9.4	F	W	19.1	35	6.4	w o g	83.500	
	3.5	C	....	19.1	37	5.8	w rp g'	64,500	
2	10.0	C'	NW	19.1	34	5.8	w rp g'	64,500	
	1.5	C	NW	19.1	36	5.8	w rp g	64,500	
	3.5	C	N	19.1	33	5.8	w r g	64,500	
	6.0	C	....	19.1	28	5.8	w r g	64,500	
3	9.3	C	N	18.1	23	5.8	w r g	64,500	
	1.0	C	....	19.1	27	6.0	w o g	70,500	Snow'.
	3.2	C	N	19.1	27	6.0	w o g	70,500	
	6.3	C	....	19.1	26	5.3	wp cor	50,500	
4	9.5	F	NW	17.1	25	5.3	wp cor	50,500	Repeated same.
	12.8	C	W	18.1	30	5.6	w p g'	58,700	
	4.3	C	W	19.1	29	5.6	w p g'	58,700	
	6.0	F	....	19.1	28	4.8	g' b p	39,500	
5	9.2	F	N	18.1	26	6.8	w go	95,000	
	10.6	F	S	18.1	—	6.4	w o g	83,500	
	12.4	C	....	18.1	33	4.9	g b p	41,700	
	3.3	C	SW	18.1	32	5.6	w r g	58,700	
	5.0	C	....	18.1	30	4.8	w' b p	39,500	Snow at night.
6	9.3	F	NW	18.1	30	5.8	w rp g	64,500	
	1.0	F	....	18.1	35	6.0	w rg	70,500	
7	9.1	C	SW	18.1	23	6.5	w o g	86,500	
	1.6	F	....	18.1	39	5.0	w ǀ b ǀ p	43,800	
	4.6	F	W	19.1	37	6.0	w r g	70,500	
	6.0	F	....	19.1	36	6.3	w o g	80,500	
8	9.5	C	S	18.1	29	4.9	g' ǀ b ǀ p	41,700	Snow'.
	12.0	C	NE	18.1	31	4.8	w r g	39,500	Do.
	4.1	C	N	19.1	31	4.9	w o g'	41,700	
9	9.6	F	W	17.1	23	6.8	w o bg	95,000	
	12.0	F	W	18.1	25	6.9	w go bg	100,000	
	3.7	F	W	17.1	24	6.8	w ro g	95,000	
	6.0	F	....	18.1	20	6.8	w ro g	95,000	
10	9.5	C	N	18.1	15	5.8	w rp g	64,500	
	9.8	C	....	—	—	6.6	w yo g	90,000	
	12.0	C	N	18.1	17	6.8	w' y bg	95,000	

TABLE 60.—Number of nuclei (n) per cubic centimeter, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	s.	Corona colors.	n. Number.	Remarks.
1904.	*Hour.*			°C	°F	*cm.*			
Dec. 10	4.0	C	N	18.1	16	6.8	g′ y′ bg	95,000	Snow′.
11	9.0	F	N	19.1	11	6.8	g′ y′ bg	95,000	
	12.7	F	NW	21.1	19	6.0	y′ r g	70,500	
	6.0	F	....	22.1	20	6.1	w r g	73,300	
12	9.5	C′	N	21.1	19	7.1	w y g	120,000	
	12.0	C	NE	—	26	4.8	w r g	39,500	
	3.7	Sn!	E	20.1	26	4.9	w | b | p	41,700	
13	9.0	Sn!	N	22.1	21	6.1	w r g	73,300	
	12.0	C	NE	22.1	25	5.9	w c g	68,000	
	4.0	C	....	21.1	28	5.1	wbr cor	46,000	
14	9.2	F	NW	22.1	13	7.1	gy o bg	90,000	
	12.5	F	....	21.1	21	7.0	gy o bg	90,000	
	3.5	F	....	20.1	23	5.8	w c g	64,500	
	5.6	F	....	21.1	20	6.4	w o g	83,500	
15	9.0	F	N	21.1	14	6.7	g b p	92,500	
	12.4	C′	....	20.1	26	7.0	w oy bg	100,000	Repeated same.
	3.0	C	....	—	28	6.7	w o g	92,500	
	5.4	C	....	21.1	28	6.1	w r g	73,300	
16	9.0	C	N	22.1	30	6.7	g b p	92,500	
	5.6	F	....	22.1	29	6.0	w c g	70,500	
17	8.7	F	NW	18.1	20	6.9	w p cor!	100,000	
	12.1	F	....	20.1	30	6.2	w r g	76,500	
	3.4	C	S	21.1	30	5.6	wp cor	58,700	
	6.4	C	....	21.1	30	6.3	w r g	80,500	Snow! at night.
18	10.3	C	NW	23.1	31	4.8	g′ b p	39,500	
	12.3	F	W	23.1	32	5.0	w | b | r	43,800	
	5.5	F	....	23.1	29	5.5	wp cor	56,200	
19	9.7	C′	S	23.1	27	6.3	w r g	80,500	
	12.3	C	....	23.1	34	5.7	wp cor	61,500	
	5.1	C	....	23.1	40	6.4	w r g	83,500	
20	9.2	F	NW	22.1	30	6.7	w yo g′	92,500	
	12.7	F	W	23.1	35	6.0	w c g	70,500	
	3.7	C′	W	23.1	34	6.6	w o g	90,000	
21	8.8	C	W	23.1	31	6.0	w c g′	70,500	
	12.7	F	N	23.1	31	7.0 6.7	w y′ g′ g b p	120,000	
	4.0	C′	NW	23.1	28	5.8	w c g	64,500	
	5.8	F	....	23.1	22	5.2	wp cor	48,200	
22	10.0	C	W	22.1	25	6.6 6.8	g b p g b p	90,000	
	12.7	C	SW	22.1	32	7.0	gy o g′	90,000	
	4.7	C	....	22.1	31	6.2	w r g	76,500	
	6.0	C	....	—	31	6.4	w o g	83,500	
23	10.1	C	SW	23.1	40	5.4	w p g′	54,200	
	1.0	C	SW	23.1	47	5.5	wp cor	56,200	
	4.7	C	....	23.1	46	5.5	wp cor	56,200	
	6.0	C	....	23.1	46	5.5	w p g	56,200	
24	10.0	C	N	25.1	34	4.9	w o cor	41,700	
	12.7	C	....	24.1	29	4.0	w br cor	22,000	
	4.7	C	....	24.1	25	4.5	w r cor	32,400	
	6.0	C	....	—	—	4.5	w ro g	32,400	
25	10.4	F	N	23.1	15	6.3	w′ r g	80,500	
	12.5	F	....	23.1	22	5.8	w c g	64,500	
	5.2	F	....	23.1	21	5.5	wp cor	56,200	
26	9.6	C	N	22.1	21	6.2	w r g	76,500	Do.
	12.0	C	N	22.1	25	5.8	w c g′	64,500	
	3.3	C	....	22.1	28	5.6	wp | g′	58,700	
	6.3	C	....	22.1	29	5.3	w P cor	50,500	
27	9.7	R	SE	23.1	38	4.8	woy cor	39,500	
	12.6	R	S	22.1	41	4.9	w | B | p	41,700	Foggy.
	4.0	R′	N	22.1	42	6.1	w rg	73,300	Do.
	6.7	Fog	....	22.1	39	4.8	g b p	39,500	Rain! at night.
28	10.0	R	E	23.1	39	6.7	w o bg	92,500	Fog.
	12.3	F′	W	23.1	47	5.3	w P cor	50,500	
	3.5	F′	....	23.1	42	6.6	w ro bg	90,000	
	6.0	F	....	23.1	34	5.8	w P | g	64,500	
31	11.3	F	S	23.1	43	6.0	w r g	70,500	
	12.5	C′	SW	23.1	46	6.1	w r g	73,300	
	5.9	F	....	23.1	44	5.8	w P | g	64,500	
1905. Jan. 1	9.3	F	NW	25.1	46	5.0	w o cor	43,800	Thaw.
	12.7	F	W	26.1	57	4.6	w r cor	34,800	

Table 60. Number of nuclei (n) per cubic centimeter, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	s.	Corona colors.	n. Number.	Remarks.
1905.	*Hour.*			°C	°F	*cm.*			
Jan. 1	5.6	F	....	25.1	44	3.9	cor	20,500	
2	9.5	C′	S	26.1	41	5.1	w br b | r	46,000	
	12.0	C	S	26.1	44	5.8	w c g	64,500	
	5.7	C R′	....	25.1	44	6.8	w o g	95,000	
3	9.4	C R′	NE	23.1	37	3.5	cor	15,000	
	12.6	C	E	23.1	34	4.0	cor	22,000	
	3.5	C Sn!	....	22.1	30	3.7	cor	17,500	
	5.8	C Sn	....	22.1	26	4.7	w b p	37,200	
4	9.8	C Sn!	N	22.1	17	7.0	y o bg	120,000	
	12.7	F	N	21.1	18	6.9	y o g	100,000	
	3.3	F	....	21.1	17	6.8	y or g	95,000	
	6.0	F	....	21.1	12	6.0	w c g	70,500	
5	10.0	F	W	20.1	14	6.2	w c g	76,500	
	12.8	F	W	20.1	22	6.6	y o g	90,000	
	6.0	F	....	20.1	18	6.0	w c g	70,500	
6	9.5	C Sn	....	20.1	14	6.8	y′ o g	95,000	
	12.7	C	....	20.1	20	6.0	w c g	70,500	
	5.8	C	....	20.1	30	6.0	w c g	70,500	Rain! at night.
7	9.5	R!	....	22.1	49	4.7	w o | g	37,200	Gale.
	12.6	C	S	22.1	48	5.6	w P cor	58,700	
8	9.7	F	W	18.1	32	5.7	w P cor	61,500	
	1.0	F	W	17.1	34	6.0	w c g	70,500	
	6.0	F	....	16.1	31	5.3	w P cor	50,500	
9	9.0	F	W	17.1	25	6.2	w c g	76,500	
	11.8	F	NW	17.1	31	5.0	w P cor	43,800	
	4.3	F	SW	17.1	32	6.3	w c g	80,500	
10	10.0	F	W	20.1	37	5.7	w P cor	61,500	
	12.7	F′	W	20.1	39	4.3	g′ B p	28,000	
	6.0	F	....	20.1	29	4.9	w | B | p	41,700	
11	9.1	C	....	21.1	24	4.7	g′ | B | p	37,200	
	4.3	C	....	20.1	31	4.7	w′ | B | p	37,200	
	6.0	C	....	21.1	32	4.6	w′ | B | p	34,800	
12	9.5	C R′	S	22.1	35	5.1	w P cor	46,000	
	12.0	C	....	22.1	39	6.6	w o g	90,000	Fog.
	3.5	R	N	22.1	40	5.3	w Br cor	50,500	
13	9.0	F	NW	23.1	28	5.3	w Br cor	50,500	
	4.0	C	N	21.1	28	6.8	w o g	95,000	
	6.0	F′	....	21.1	26	5.8	w c | g	64,500	
14	10.1	F	N	21.1	19	6.4	w c g	83,500	
	1.3	F	NW	19.1	24	6.7	w o g	92,500	
	4.3	F	W	19.1	20	5.4	w Br cor	54,200	
	6.1	F	....	20.1	18	5.5	w P | g	56,200	
15	10.7	F	W	20.1	18	6.8	w o g	95,000	
	12.7	F	W	20.1	21	6.6	w o g	90,000	
	6.0	F	....	20.1	22	5.8	w P g	64,500	
16	9.4	F	W	20.1	22	6.4	w o g	83,500	
	5.0	F	....	19.1	28	6.9	g y o bg	100,000	
17	9.7	F	W	20.1	28	6.0	w c g	70,500	
	1.0	C	....	19.1	35	6.0	w c g	70,500	
	6.0	—	....	21.1	36	6.2	w r g	76,500	
18	9.4	C′	W	22.1	33	6.0	w c g	70,500	
	4.2	C	N	21.1	34	4.4	cor	30,000	
	6.0	C	....	21.1	34	4.4	w r g	30,000	
19	9.3	F	SW	22.1	39	5.3	w Br cor	30,500	
	12.3	F	W	21.1	46	5.7	w P cor	61,500	
	5.0	F	W	21.1	45	6.0	w c g	70,500	
20	9.7	F	W	22.1	41	4.7	g | b | p	37,200	
	11.2	F	....	22.1	41	4.8	g | b | p	39,500	
	6.3	F	....	22.1	36	5.5	w P cor	56,200	
21	9.7	F	NW	—	31	5.1	w Br cor	46,000	
	1.0	C′	....	21.1	37	5.1	w Br cor	46,000	
	6.1	C Sn	....	22.1	34	5.4	w Br cor	54,200	
22	9.7	C R′	S	22.1	49	5.7	w C	61,500	
	1.0	C	W	—	40	3.8	cor	19,000	
	6.2	C	....	23.1	38	4.7	w o g	37,200	
23	9.3	F	N	22.1	18	6.9	g b p	100,000	
	12.3	F	NW	20.1	22	5.7	w c g	61,500	
	5.0	F	....	20.1	21	5.7	w c g	61,500	
24	9.4	F	N	21.1	14	5.7	w c g	61,500	
	1.2	F	NW	20.1	25	4.8	w or g	39,500	
	5.7	F	....	20.1	26	4.7	g′ B p	37,200	
25	10.3	Sn	....	20.1	15	5.9	w c g	68,000	Gale and drift.

TABLE 60.—Number of nuclei (*n*) per cubic centimeter, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	*s*.	Corona colors.	*n*. Number.	Remarks.
1905.	*Hour.*			°C	°F	*cm.*			
Jan. 25	12.4	Sn	....	20.1	15	6.3	w r g	80,500	Blizzard.
	5.7	Sn	....	19.1	11	7.0	gy o bg	90,000	
26	9.5	F	NW	19.1	10	7.0	gy o bg	90,000	
	12.7	F	N	18.1	16	6.6	g (v) B p	100,000	
	6.0	F	....	20.1	16	5.9	w c g	68,000	
27	9.1	F	NW	20.1	17	7.1	g′ o bg	90,000	
	12.2	F	W	20.1	27	6.9	g′ o bg	90,000	
	6.4	F	....	21.1	27	6.5	w r g	86,500	
28	9.7	Sn′	SW	22.1	27	6.6	w c g	90,000	
	11.6	C	....	22.1	32	6.5	w r g	86,500	
	5.6	C	....	23.1	24	5.1	w | B | p	46,000	*s* = 5.5 close up.
29	9.6	F	NW	22.1	19	6.9	w or g	100,000	*s* = 7.7 close up.
	12.7	F	W	22.1	26	4.8	g′ B p	39,500	
	6.0	F	....	—	25	6.1	w c g	73,300	*s* = 7.3 close up.
30	9.3	C	....	22.1	21	5.8	w P g′	64,500	*s* = 6.8 close up.
	3.5	C	....	21.1	24	6.9	w y bg	100,000	*s* = 7.7 close up.
	5.0	C	....	21.1	23	6.4	w r g	83,500	*s* = 7.3 close up.
31	9.5	F	N	21.1	17	7.1	gy o bg	120,000	*s* = 7.9 close up.
	12.6	F	....	21.1	23	7.0	w o g	120,000	*s* = 7.8 close up.
	3.2	F	....	20.1	23	5.7	w P cor	61,500	*s* = 6.6 close up.
	6.1	F	....	21.1	22	6.9	w yo g′	100,000	*s* = 7.9 close up.
Feb. 1	9.5	F	NW	20.1	17	6.1	w c g	73,300	*s* = 7.4 close up.
	12.4	F	....	—	26	7.2	w y g	120,000	
	6.0	F	....	20.1	27	6.2	w c g	76,500	*s* = 7.4 close up.
2	9.4	F	W	21.1	23	4.9	g′ B p	41,700	*s* = 5.8 close up.
	3.5	F	....	20.1	22	5.8	w P g′	64,500	*s* = 6.6 close up.
3	9.4	F	W	20.1	10	6.7	y′ o bg	92,500	
	12.3	F	....	20.1	17	6.8	y′ o bg	95,000	
	5.7	F	....	21.1	16	6.8	w o bg	95,000	
4	9.8	F	NW	20.1	10	7.0	g B P	120,000	
	12.9	F	W	19.1	16	7.6	gy o bg	120,000	
	4.0	F	NW	—	18	5.8	w P cor	64,500	
	6.0	F	....	20.1	17	6.6	g B P	90,000	
5	9.8	F	N	19.1	15	6.7	g B P	92,500	
	10.8	F	....	—	—	6.9	g B P	100,000	
	12.9	F	W	20.1	25	6.7	w r g	92,500	
	4.8	F	S	20.1	25	5.0	w | B | P	43,800	
6	9.3	Sn!	NE	21.1	28	4.8	g′ | B | P	39,500	
	12.0	R	E	21.1	32	4.8	g′ | B | P	39,500	
	5.0	R	N	21.1	35	6.6	G B P	90,000	
	6.0	R′	....	—	—	—	g y o bg	(90,000)	
7	9.2	F	W	22.1	22	6.8	w o g	95,000	
	12.5	F	NW	21.1	23	6.0	w C g	70,500	
	4.3	F	N	21.1	25	6.9	y o bg	100,000	
	6.0	F	....	21.1	22	5.9	w c g	68,000	
8	9.6	F	N	20.1	21	{ 6.4 6.6 }	v′ | B | R O	83,500	
	12.4	F	....	20.1	30	6.7	g B P	92,500	
	4.9	F	N	21.1	31	6.0	w c g	70,500	
	6.0	F	....	—	31	6.8	gy o bg	95,000	
9	9.5	Sn!	N	22.1	26	5.5	w P cor	56,200	
	12.5	C	E	21.1	35	3.8	cor	19,000	Small corona for east wind.
	3.7	R	E	20.1	35	4.3	w R | g	28,000	
	5.0	R′	NE	20.1	34	4.3	w R | g	28,000	
10	9.8	F	W	23.1	37	5.1	w P cor	46,000	
	12.1	C	NW	23.1	41	5.0	g′ | B | P	43,800	
	4.5	C′	NW	21.1	34	4.4	w R gr	30,000	
	6.0	F	....	21.1	31	5.2	w | B | p	48,200	
11	9.3	F	W	22.1	21	6.4	w r g	83,500	
	12.1	F	NW	21.1	25	6.5	w r g	86,500	
	5.1	F	W	—	24	6.1	w c g	73,300	
12	9.5	C	W	20.1	20	6.7	w r g	92,500	
	12.5	C	W	20.1	23	6.8	w o g	95,000	
	5.0	C Sn	W	21.1	29	5.6	w P cor	58,700	
13	9.4	R′	W	22.1	41	5.6	w P cor	58,700	
	3.8	R′	....	20.1	29	4.8	w o g	39 500	
	5.0	—	....	—	25	4.8	w o g	39,500	
14	9.3	F	W	20.1	10	6.8	y o bg	95,000	
	12.4	F	W	20.1	14	6.5	w o g	86,500	
	5.8	F	W	—	17	6.8	y o bg	95,000	
15	9.5	F	W	20.1	20	6.1	w c g	73,300	Haze.

TABLE 60.—Number of nuclei (n) per cubic centimeter, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	s.	Corona colors.	n. Number.	Remarks.
1905.	*Hour.*			°C	°F	*cm.*			
Feb. 15	5.6	F	NW	20.1	25	5.2	w | B ¦ P	48,200	
16	11.8	F	NW	19.1	16	6.9	g B P	100,000	
	3.5	F	NW	20.1	21	6.0	w C g	70,500	
	6.0	F	....	20.1	19	6.7	w or g	92,500	
17	9.0	C	SW	20.1	28	6.9	w o g	100,000	
	12.3	C	SW	20.1	36	6.4	w r g	83,500	
	4.3	C	SW	20.1	35	6.4	w r g	83,500	
	6.5	C	....	20.1	34	5.6	w P cor	58.700	
18	8.9	F	W	22.1	21	6.6	w o g	90,000	
	12.5	F′	NW	22.1	23	6.4	w o g	83,500	
	5.9	F	NW	21.1	18	6.0	w r g	70,500	
19	10.3	F	....	21.1	17	6.7	w o g	92,500	
	12.7	F	W	21.1	21	7.0	w o bg	120,000	
	4.8	F	....	21.1	24	5.0	g′ B P	43,800	
	6.4	F	....	21.1	23	6.2	w R g	76,500	
20	7.9	C	....	21.1	34	6.2	w C g	76,500	
	12.3	Sn|	....	20.1	33	5.6	w P cor	58,700	
	6.0	K′	....	21.1	36	5.7	—	61,500	
21	9.7	F	N	23.1	41	6.2	w r g	76,500	
	12.2	F	N	23.1	45	6.0	w c | g	70,500	
22	9.5	C	NE	23.1	32	4.3	w P cor	28,000	
	12.3	C	NE	23.1	33	4.8	cor	39,500	
	5.8	C	....	23.1	31	4.3	cor	28,000	
23	9.4	F	NE	22.1	21	7.1	g′ o bg	90,000	
	12.0	F	....	22.1	26	6.9	y o g	100,000	
	5.1	F	NE	23.1	33	5.2	w Br cor	48,200	
24	9.7	C	N	22.1	33	6.8	g B P	95,000	
	12.3	C	....	—	38	—	—	—	
	4.0	F	NW	23.1	41	5.7	w P | g	61,500	
26	9.7	C′	....	23.1	36	6.7	w o g	92,500	
	12.4	C	S	23.1	40	5.0	w br cor	43,800	
	5.5	C	W	23.1	40	4.4	w r cor	30,000	
27	9.4	F	W	23.1	24	6.8	w o g	95,000	
	4.3	F	W	20.1	30	5.8	w P cor	64,500	
28	9.3	F	W	23.1	30	4.9	g′ B P	41,700	
	12.7	C	W	21.1	38	6.4	w o g	83,500	
	3.9	F	W	21.1	39	4.8	g′ B p	39,500	
	6.1	F	....	22.1	38	4.7	g′ B p	37,200	
Mar. 1	10.1	F	W	21.1	29	6.0	w C g	70,500	
	12.4	F	W	20.1	32	6.0	w c g	70,500	
	6.2	F	....	21.1	30	5.4	cor	54,200	
2	9.3	F	NW	20.1	22	6.5	wog	86,500	
	3.5	F	W	20.1	32	5.1	w Br cor	46,000	
	5.0	F	....	20.1	31	5.4	w P cor	54,200	
3	9.7	F	W	21.1	30	6.8	w o g	95,000	
	12.2	F	W	20.1	35	6.3	w r g	80,500	
	6.3	F	....	22.1	36	5.6	w P cor	58,700	
4	9.2	C′	S	23.1	37	5.9	w r g	68,000	
	12.0	C	W	22.1	43	4.7	w r g	37,200	
	5.8	F	N	22.1	35	5.3	cor	50,500	
5	9.7	F	N	21.1	23	6.2	w o g	76,500	
	1.1	F	S	21.1	29	5.5	w P cor	56,200	
	7.0	F	....	21.1	28	5.0	w Br cor	43,800	
6	9.2	F	NW	22.1	29	6.8	wog	95,000	
	4.3	F	N	20.1	35	4.8	cor	39,500	
	6.7	F	....	20.1	33	5.9	w r g	68,000	
7	9.7	F	S	21.1	31	5.2	w br cor	48,200	
	1.0	C′	S	21.1	38	4.7	w | B | P	37,200	
	6.1	C	....	21.1	35	4.7	w | B | P	37,200	
8	9.5	C	N	21.1	39	5.7	w r g	61,500	Fog.
	3.2	C	W	21.1	42	6.4	w r g	83,500	Fog.
	5.3	C	SW	21.1	40	4.7	w B P	37,200	
9	9.5	F	NW	23.1	40	4.7	w B P	37,200	
	1.4	C′	S	23.1	45	4.6	w r g	34,800	
	5.0	C	S	—	40	4.6	w o g	34,800	Rain! at night.
10	9.2	C	N	23.1	40	4.9	w o g	41,700	
	5.1	C	S	23.1	47	4.9	w o g	41,700	
11	9.3	F	W	23.1	31	7.0	w o bg	90,000	
	1.0	F	....	23.1	35	6.1	w r g	73,300	
	6.0	F	W	23.1	32	4.8	w B P	39,500	
12	9.8	F	W	23.1	36	5.6	w P cor	58,700	
	4.6	C′	....	23.1	41	5.0	g′ B P	43,800	

TABLE 60.—Number of nuclei (n) per cubic centimeter, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	s.	Corona colors.	n. Number.	Remarks.
1905.	*Hour.*			°C	°F	*cm.*			
Mar. 13	9.5	F	N	22.1	29	5.5	w P cor	56,200	
	12.3	F	W	22.1	34	5.9	w r g	68,000	
	6.3	F	S	22.1	31	6.2	w c g	76,500	
14	9.3	F	N	20.1	31	5.3	cor	50,500	
	12.5	F	N	21.1	38	4.9	wo cor	41,700	
	6.3	F	....	21.1	32	4.8	wo cor	39,500	
15	9.7	F	NE	22.1	31	6.0	w c g	70,500	
	12.0	F	N	22.1	37	5.6	w P cor	58,700	
	5.8	F	S	22.1	35	5.0	—	43,800	
16	9.7	F	NW	22.1	43	5.7	w P cor	61,500	
	1.0	F	....	22.1	49	4.8	g′ B P	39,500	
	6.0	F	....	23.1	44	4.6	cor	34,800	
17	9.5	F	NE	23.1	39	5.0	w | B | P	43,800	
	2.6	F	S	23.1	46	4.7	g′ B P	37,200	
	6.2	F	....	23.1	39	4.5	w r g	32,400	
18	9.6	F	S	23.1	46	4.8	g B P	39,500	
	1.5	F	S	23.1	63	4.8	g B P	39,500	
	6.5	F	....	23.1	52	4.6	w r g	34,800	
19	9.6	R′	W	22.1	53	4.5	w o g	32,400	
20	9.7	R′	NE	20.1	36	3.8	cor	19,000	
	6.0	C	....	20.1	34	4.8	w B P	39,500	
21	9.4	C R′	NE	20.1	36	3.5	cor	15,000	
	3.3	R Sn	....	20.1	34	3.6	cor	16,200	
	6.0	R′	....	20.1	32	3.7	cor	17,500	
22	9.5	C	N	21.1	35	5.2	w P cor	48,200	
	12.6	C′	N	21.1	41	4.8	w y g	39,500	
	6.0	F	NE	22.1	37	4.8	w y g	39,500	
23	9.4	F	SE	19.1	39	4.8	g B P	39,500	
	1.0	F	S	—	44	4.8	g B P	39,500	
	6.2	F	....	21.1	38	5.5	w c g	56,200	
24	9.3	C	S	22.1	40	5.4	w P cor	54,200	
	1.3	C	....	22.1	43	4.8	w r g	39,500	
25	9.5	R	S	23.1	48	4.7	w r g	37,200	
	1.3	C	....	23.1	53	4.8	w o g	39,500	
26	10.0	F	W	24.1	52	4.8	w B P	39,500	
	1.5	F	W	24.1	60	5.3	w P cor	50,500	
	6.8	F	S	24.1	48	4.6	w r g	34,800	
27	9.5	C	SW	25.1	54	4.9	w o g	41,700	
	3.0	C	W	24.1	58	4.9	w o g	41,700	
	5.5	F	W	24.1	55	4.7	W B P	37,200	
28	9.1	F	W	24.1	56	4.7	g B p	37,200	
	6.4	F	W	24.1	62	5.6	w c g	58,700	
29	8.7	F	NE	23.1	57	4.6	w r g	34,800	
	6.4	F	S	22.1	53	4.6	w r g	34,800	
30	10.3	C′	S	21.1	52	4.0	cor	22,000	
	12.7	F	S	21.1	54	3.7	cor	17,500	
	6.2	F	....	21.1	—	4.6	—	34,800	
31	9.2	F	W	19.1	57	5.6	w P cor	58,700	
	12.3	F	NW	19.1	64	5.2	w | B | P	48,200	
Apr. 1	9.5	F	NW	19.1	50	6.2	w o g	76,500	
	4.2	F	W	19.1	50	4.9	w | B | P	41,700	
	6.4	F	N	19.1	45	4.8	w P cor	39,500	
2	9.5	F	NW	17.1	37	5.3	w P cor	50,500	
	1.5	F	NW	17.1	45	6.5	w o g	86,500	
	6.7	F	....	17.1	41	5.8	w Cr g	64,500	
3	9.3	F	W	16.1	44	6.6	g B P	90,000	
	3.4	F	NW	17.1	57	6.1	w c g	73,300	
	6.0	F	W	17.1	54	4.8	w | B | —	39,500	
4	9.4	R′	NE	17.1	45	4.7	g B P	37,200	
	2.7	C	S	18.1	49	4.9	w o g	41,700	
	6.3	C	S	19.1	47	4.6	—	34,800	
5	9.1	C	N	20.1	46	6.0	w c g	70,500	
	3.3	R	....	20.1	47	3.8	cor	19,000	
	5.5	R	NE	21.1	46	3.8	cor	19,000	
6	9.0	R	S	22.1	49	4.6	w o g	34,800	Fog.
	12.8	C	SW	22.1	52	4.6	w o g	34,800	
	6.4	F	....	—	47	4.7	g B P	37,200	
7	9.3	F	N	20.1	44	4.8	g B P	39,500	
	3.0	F	NW	19.1	51	4.7	w B P	37,200	
	6.1	F	....	—	47	4.8	w r g	39,500	
8	9.0	C	W	18.1	41	5.0	w | B | P	43,800	
	1.5	F	....	18.1	50	5.0	cor	43,800	

TABLE 60.—Number of nuclei (n) per cubic centimeter, etc.—Continued.

Date.	Time.	Weather.	Wind.	Temp. of apparatus.	Temp. of atmosphere.	s.	Corona colors.	n. Number.	Remarks.
1905.	*Hour.*			°C	°F	*cm.*			
Apr. 8	6.0	F	NW	18.1	43	4.4	cor	30,000	
9	9.7	F	W	20.1	48	6.2	w o g	76,500	
	12.1	F	W	21.1	56	4.7	w r g	37,200	
	5.6	F	W	21.1	56	4.6	w r g	34,800	
10	9.0	F	SW	20.1	56	5.5	w P cor	56,200	
	12.5	F	....	—	65	4.9	cor	41,700	
	6.5	F	....	—	—	4.7	cor	37,200	
11	9.3	R!	NE	23.1	49	3.5	cor	15,000	
	12.3	R	N	22.1	49	3.6	cor	16,200	
	5.7	R′	NE	23.1	45	3.4	cor	13,800	
12	9.6	C	N	19.1	49	4.8	cor	39,500	
	3.4	F	N	22.1	58	4.9	w | B | P	41,700	
	6.2	F	S	22.1	52	4.8	w r g	39,500	
13	9.4	C	NE	21.1	51	4.1	cor	24,000	
	12.7	C	....	21.1	55	4.3	cor	28,000	
	6.5	C	....	—	—	3.6	cor	16,200	
14	9.4	F	W	20.1	50	6.1	w c g	73,300	
	12.4	F	....	20.1	58	5.8	wp cor	64,500	
	6.3	F	S	20.1	52	4.6	wrg	34,800	
15	9.5	F	N	18.1	48	6.4	w r g	83,500	
	1.5	F	W	19.1	54	4.8	w r g	39,500	
	6.2	F	NW	20.1	51	4.7	w r g	37,200	
16	10.3	C′	NW	19.1	49	4.8	w | B | P	39,500	
	1.1	C	W	19.1	52	3.8	cor	19,000	
	6.5	C	....	20.1	42	3.8	cor	19,000	
17	9.7	C′	W	17.1	41	5.6	wp cor	58,700	
	12.4	C	....	—	48	6.2	wp cor	76,500	
	6.3	F	....	17.1	42	5.1	w | B | P	46,000	
18	10.4	C′	....	19.1	48	5.0	w | B | P	43,800	
	1.0	C	....	20.1	49	4.9	G | B | P	41,700	
	6.0	C′	....	20.1	43	4.7	w r g	37,200	
24	3.8	F	S	20.1	58	5.9	w c g	68,000	
	6.3	F	SW	19.1	53	4.9	g B P	41,700	
25	9.7	F	NW	18.1	52	4.9	w o cor	41,700	
	12.8	F	....	19.1	60	4.9	w o cor	41,700	
	6.0	F	W	19.1	62	4.8	cor	39,500	
26	9.0	C′	SW	20.1	62	5.4	w P cor	54,200	
	4.5	R′	....	21.1	69	4.8	g B P	39,500	
27	9.6	C	NE	21.1	57	3.5	cor	15,000	
	6.1	C′	....	20.1	58	3.5	cor	15,000	
28	9.5	C	NE	20.1	51	3.2	cor	11,300	
	12.4	C′	....	20.1	57	3.0	cor	9,300	
	6.2	F	E	20.1	59	3.5	cor	15,000	
29	9.5	C	E	18.1	50	3.3	cor	12,500	
	12.5	C′	S	19.1	60	5.2	w B cor	48,200	
	3.7	—	....	20.1	—	4.0	—	22,000	
30	10.0	F	W	19.1	65	4.4	cor	30,000	
	12.7	F	S	19.1	67	4.4	cor	30,000	
	6.6	C′	NW	20.1	64	3.7	cor	17,500	
May 1	9.4	F	NW	18.1	52	4.8	wocor	39,500	
	6.5	F	....	18.1	—	4.0	cor	22,000	
2	9.7	F	NW	18.1	51	5.5	w c g	56,200	
	4.0	F	W	19.1	62	5.6	wp cor	58,700	
3	9.5	C′	W	19.1	66	5.6	w P cor	58,700	
	3.8	F	....	21.1	74	5.5	w P cor	56,200	
	6.0	F	SW	21.1	70	4.9	w B P	41,700	

All data are given in the upper curves of figures 95 to 101, the abscissas showing the current times, the ordinates the nucleations, in thousands per cubic centimeter The usual symbols of wind and weather are inserted, R denoting rain, R′ rainish, Sn snow, etc. The lower curves have already been referred to and are the cotemporaneous data found by Mr. Pierce at Block Island.

85. Comparison of the data for Providence and for Block Island.—A discussion of the details of the type of results obtained for Providence has already been given in the Smithsonian report (loc. cit.), and the new data add no essential novelty. It will suffice, therefore, to compare the two classes of curves throughout their extent.

Figures 95 to 101 show the daily record of the nucleations of Providence (upper curve) and of Block Island (lower curve) in thousands

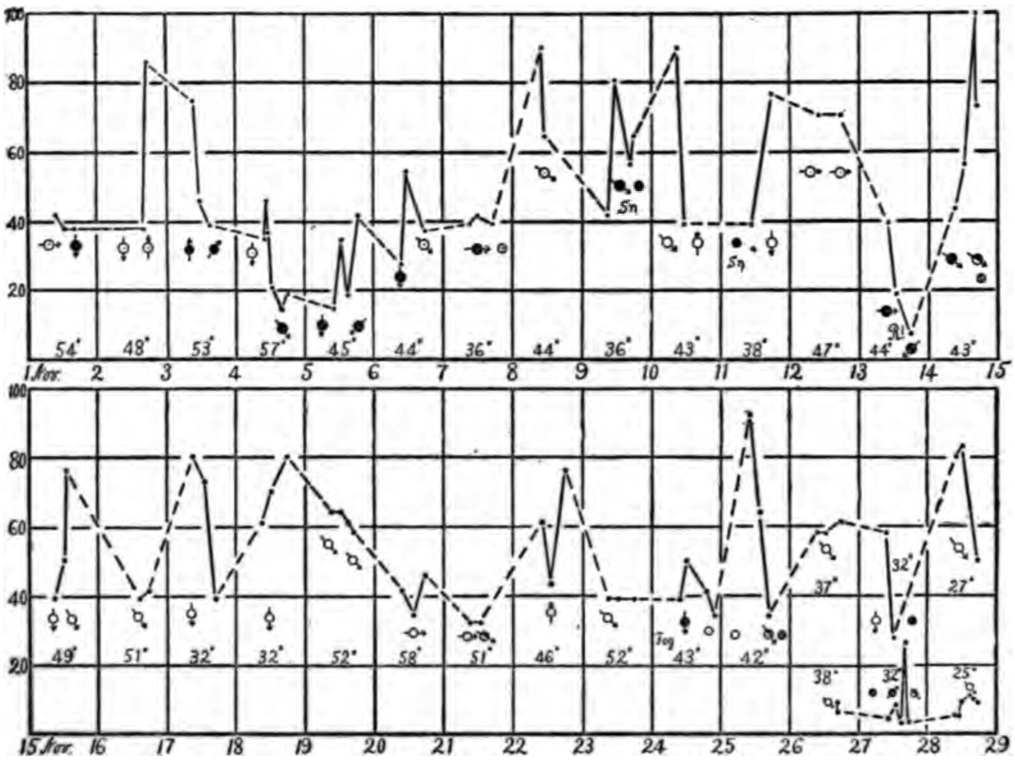

FIG. 95.—Showing daily record for November 1 to 29.

of nuclei per cubic centimeter for the dates given by the abscissas, *i.e.*, from November, 1904, to May, 1905. The prevailing winds and weather and the temperatures of both places are roughly given on the curves.

In the earlier results, from November, 1904, to January, 1905, there is as yet no striking opportunity for comparison, except that both cases show a general rise of nucleation to the high maximum following December 14 and December 20. It is clear that similarity in the two cases must be marred by the snow effect, which is necessarily of unequal value in the two cases, the depression being as a rule larger and more striking as the antecedent nucleation is higher. On December 12 the two curves behave similarly, but not so December 3, 8, 13, 18, 21. The remarkable depression of the upper curve on December

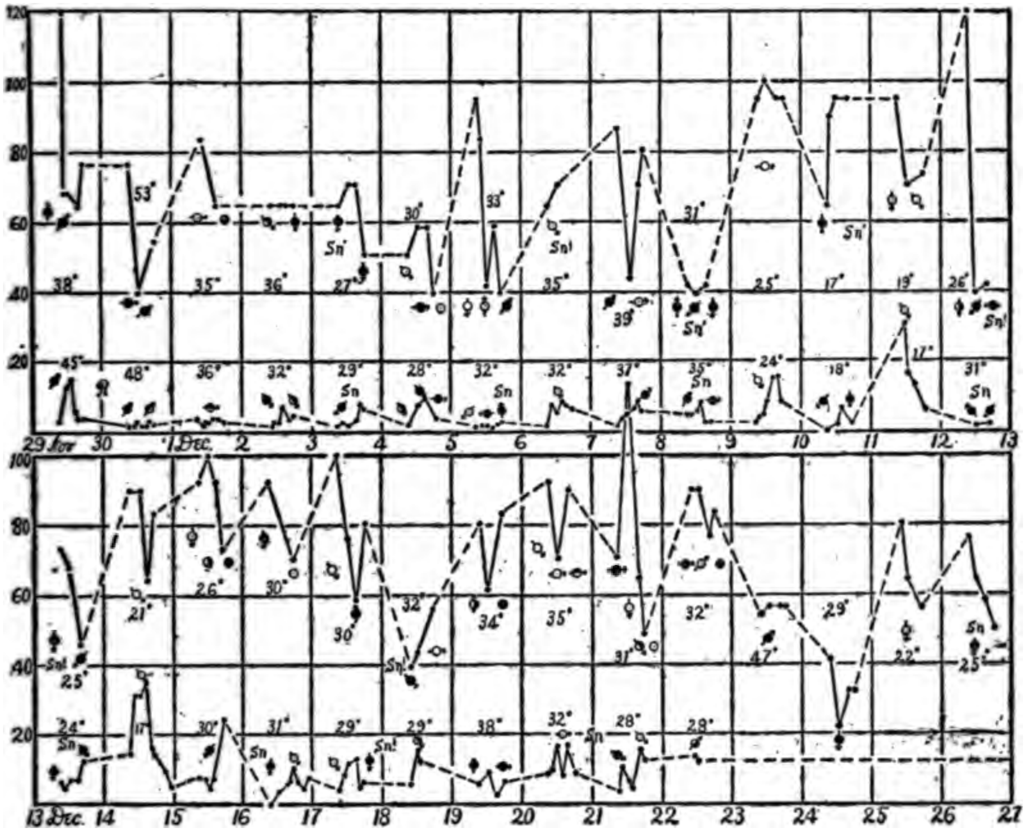

FIG. 96.—Showing daily record for November 29 to December 27.

24 is noteworthy. Some instances of detailed similarity (December 4, 9, 20, etc.) might be pointed out, but in general the curves in their details are dissimilar.

Differences in winds and temperatures, here as elsewhere, are in the main influenced by the times at which observations were severally made. The two sets of results show, as a whole (beginning with November 27), the state of high contamination of the atmosphere of Providence as compared with that of Block Island. Rarely do the former curves dip down to meet the latter, while the nucleation may be 50 or more times greater. The difference must be due (since it is exaggerated in the winter months) to the originally ionized products of combustion. The two curves give evidence of a rapid self-purification (probably due to dilution) of the atmosphere, from which it follows that the nuclei observed in Providence are to a large extent generated

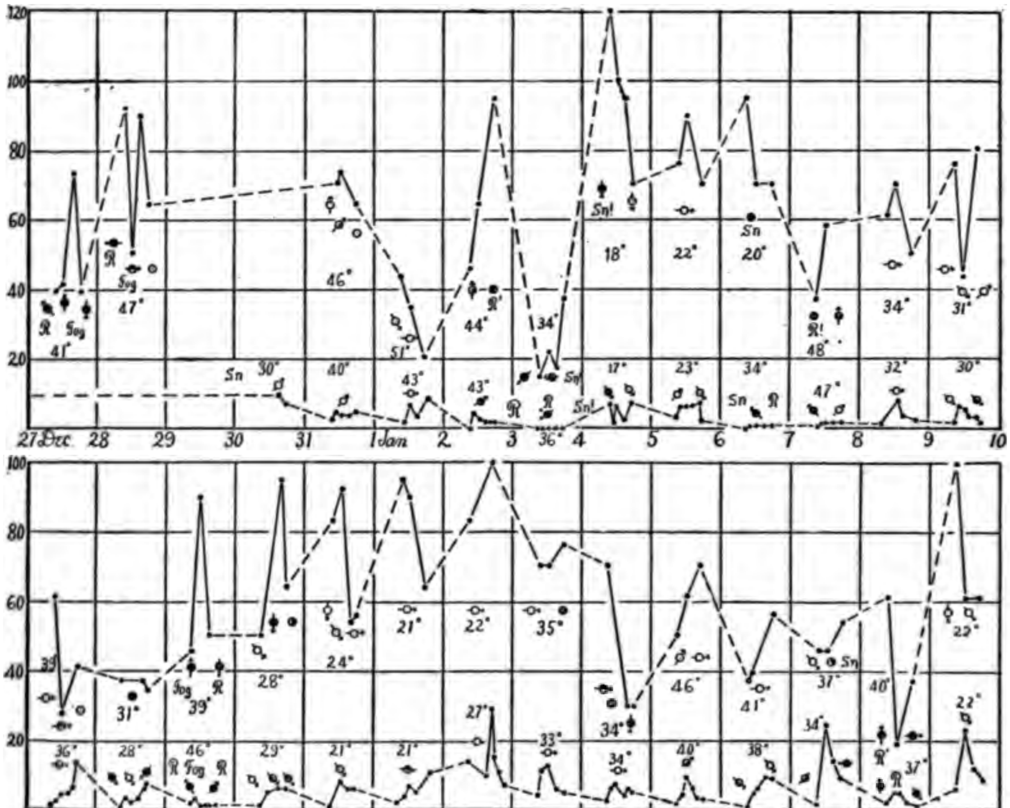

FIG. 97.—Showing daily record for December 27 to January 24.

there. It would be hazardous to assume, however, that all the nuclei are artificially generated, and Mr. Pierce is of the opinion that there is an outstanding nucleation in the Block Island results which can not in this manner be explained away.

The early part of January is subject to rains, and the sustained maximum at Providence following January 4 is but obscurely represented at Block Island. On the other hand, the maximum following

January 13 is fairly well reproduced at Block Island and coincident high values on January 16 are probably not due to chance. The same may be said of January 23.

Toward the end of February the pronounced maximum in the Block Island results (February 23–26) is in keeping with the Providence data. The sustained high wave of nucleation at Block Island from

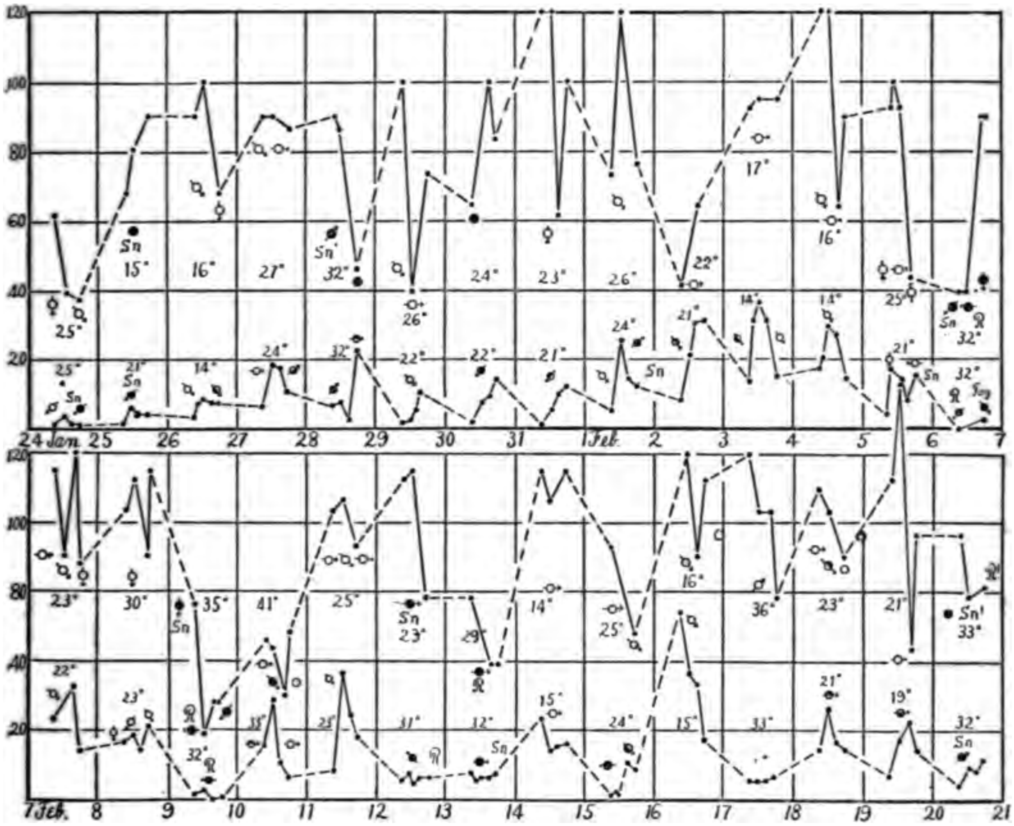

FIG. 98.—Showing daily record for January 24 to February 21.

February 26 to March 4 does not correspond to an equally sustained case at Providence, though the nucleation is at times high. In this region there are instances (not cotemporaneous, however) in which the Block Island nucleation exceeds that of Providence.

Following January 25 the extremely high nucleations which hold general sway up to February 6 are well reproduced by both curves. There are here some striking coincidences, as on February 1, 8, etc., with divergences on February 2, 3, etc. The exceptionally high results for Block Island on February 11, 14, 16, 18, penetrate, as it were, into corresponding elevations in the upper curve. In fact, between February 10 and 20 the wave of both places is of the same general type, with the Providence data somewhat behind the other in phase. This is one of the most interesting parts of the results. It may be seen more or less clearly on February 3, 4, 7, 11, 14, 16, 18.

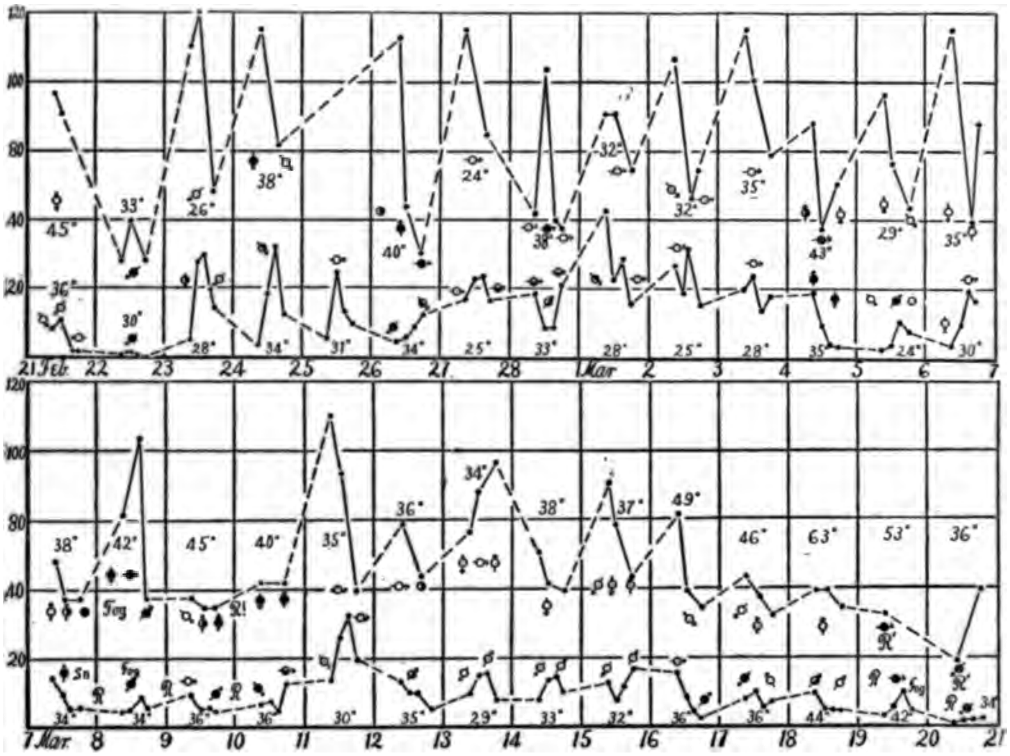

FIG. 99.—Showing daily record for February 21 to March 21.

Late in March (8–20) there is a final attempt at a sustained maximum at Block Island, while the Providence data gradually decrease to the rain on March 20. From March 20 to March 31 both curves are relatively low. March 31 to April 4, April 6 to April 11, April 14 to April 18, show a distinct tendency of both curves to pass through moderate maxima. The remaining data to March 4 are too low for further comparison. As a whole, therefore, little more than a general correspondence can be made out, in which the correspondence of exceptionally high winter nucleation correspond in the data of both stations.

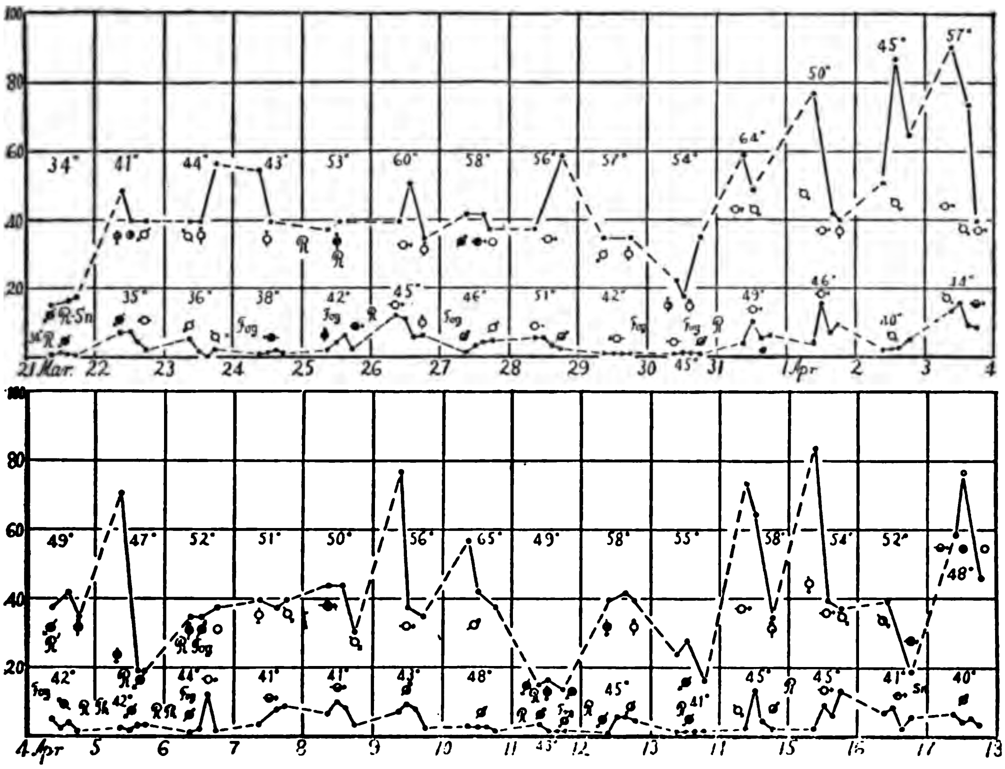

FIG. 100.—Showing daily record for March 21 to April 18.

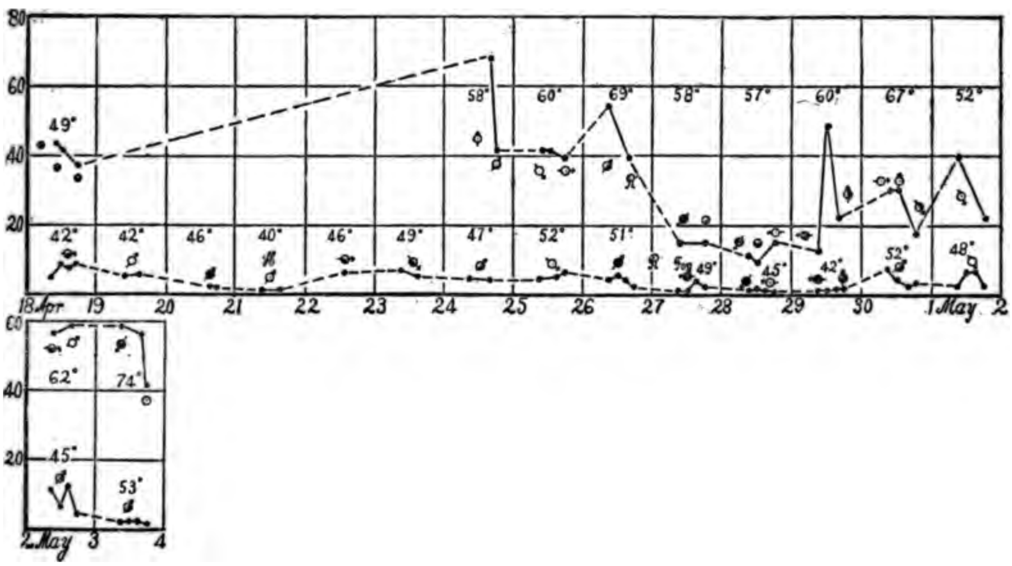

FIG. 101.—Showing daily record for April 18 to May 4.

TABLE 61.—Average daily nucleations of the atmosphere at Providence, 1904–5.

Date.	Weather.	$N \times 10^{-3}$.	Date.	Weather.	$N \times 10^{-3}$.	Date.	Weather.	$N \times 10^{-3}$.
1904.			1905.			1905.		
Nov. 1	FC	39	Jan. 1	F	33	Mar. 2	F	62
2	F	54	2	CR′	68	3	F	78
3	C	53	3	CR Sn	23	4	CF	52
4	F	29	4	C Sn F	96	5	F	59
5	C	27	5	F	79	6	F	67
6	CF	42	6	C Sn	79	7	FC	41
7	CF	40	7	R	48	8	C	61
8	F	77	8	F	61	9	FC	36
9	Sn	61	9	F	67	10	C	42
10	F	62	10	F	43	11	F	61
11	CF	58	11	C	36	12	FC	51
12	F	71	12	CR	62	13	F	67
13	R	22	13	FC	70	14	F	44
14	CF	73	14	F	95	15	F	58
15	F	55	15	F	83	16	F	44
16	F	41	16	F	92	17	F	38
17	F	64	17	FC	72	18	F	38
18	F	71	18	C	43	19	R′	32
19	F	62	19	F	61	20	R′C	29
20	F	41	20	F	44	21	R Sn	16
21	F	32	21	FC Sn	49	22	C	42
22	F	60	22	C	39	23	F	45
23	F	39	23	F	78	24	C	47
24	CF	42	24	F	46	25	RC	38
25	FC	62	25	Sn	80	26	F	41
26	F	59	26	F	86	27	CF	40
27	FC	43	27	F	89	28	F	48
28	F	71	28	Sn′ C	74	29	F	35
29	C	80	29	F	71	30	F	25
30	C	57	30	C	83	31	F	53
Dec. 1	FC	74	31	F	100	Apr. 1	F	52
2	C	64	Feb. 1	F	90	2	F	67
3	C	64	2	F	53	3	F	67
4	FC	52	3	F	93	4	R′C	38
5	FC	63	4	F	98	5	R	36
6	F	67	5	F	82	6	RF	36
7	CF	70	6	Sn′ R	65	7	F	39
8	C	41	7	F	84	8	CF	39
9	F	96	8	F	85	9	F	49
10	C	86	9	Sn R	33	10	F	45
11	F	80	10	FC	42	11	R	15
12	Sn	67	11	F	81	12	CF	40
13	Sn	62	12	C Sn	82	13	C	23
14	F	82	13	R	44	14	F	57
15	FC	90	14	F	92	15	F	53
16	CF	81	15	F	61	16	C	26
17	FC Sn	79	16	F	88	17	CF	60
18	CF	43	17	C	81	18	C	41
19	C	75	18	F	81	..	....	..
20	F	84	19	F	83	24	F	55
21	CF	76	20	Sn R	65	25	F	41
22	C	85	21	F	73	26	CR′	47
23	C	56	22	C	32	27	C	15
24	C	32	23	F	79	28	CF	12
25	F	67	24	CF	78	29	C	28
26	C	62	25	....	..	30	FC	26
27	R	48	26	C	55	May 1	F	31
28	RF	74	27	F	80	2	F	57
..	....	..	28	F	51	3	F	52
31	F	69	Mar. 1	F	65			

86. Average daily nucleations.—These are given in table 61, together with the date and the weather. They are further shown in the chart, figure 102, where the abscissas denote the successive days and the ordinates are the corresponding nucleations in thousands per cubic centimeter. The different points are distinguished by the usual Weather Bureau symbols, ● ◑ ⊙, r, Sn, etc., so that the weather conditions are included in the curves.

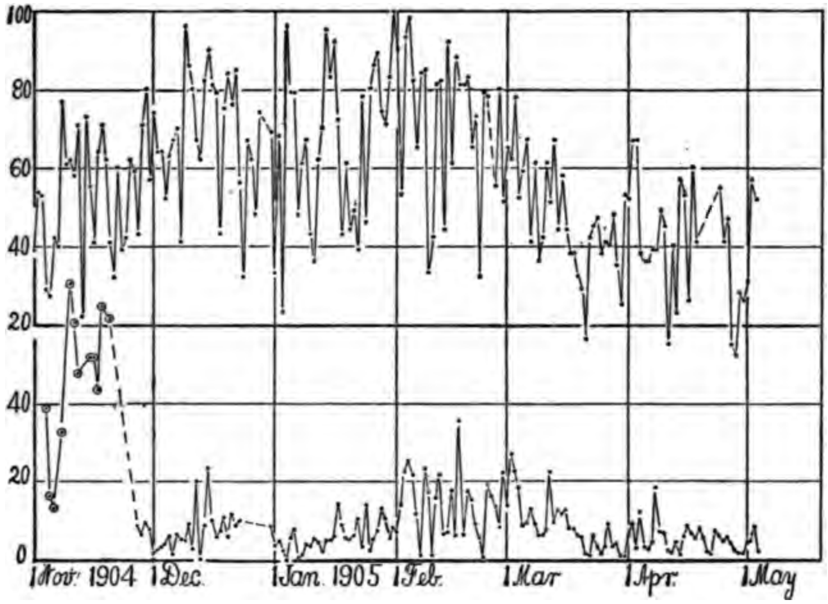

FIG. 102.—Average daily nucleations in thousands per cubic centimeter at Providence (upper curve) and at Block Island (lower curve, excepting the data marked with a circle, which were taken at Providence) for November, 1904, to May, 1905.

This curve is quite distinct from the types obtained in 1902–3 and 1903–4 and shown in my earlier report,* inasmuch as the new curve has an incidental strongly marked maximum in February. Other features, however, appear as in the earlier figures. Thus, there is a definite tendency to reach a maximum in December.

* Smithsonian Contributions, Vol. XXXIV, 1905.

TABLE 62.—Average monthly nucleations.

Month.	Providence.	Block Island.	Ratio.
	$n \times 10^{-3}$.	$n' \times 10^{-3}$.	n/n'.
November.	53.0	<(7.0)	....
December.	68.6	7.1	9.7
January...	66.1	5.4	12.3
*February..	71.5	13.9	5.1
March....	47.0	7.9	5.9
April.....	40.3	5.0	8.1
May......	....	<(5.1)	....

*The February effect, which is merely superimposed at Providence, becomes fundamental at Block Island. The ratios show that it outlasts March and even April.

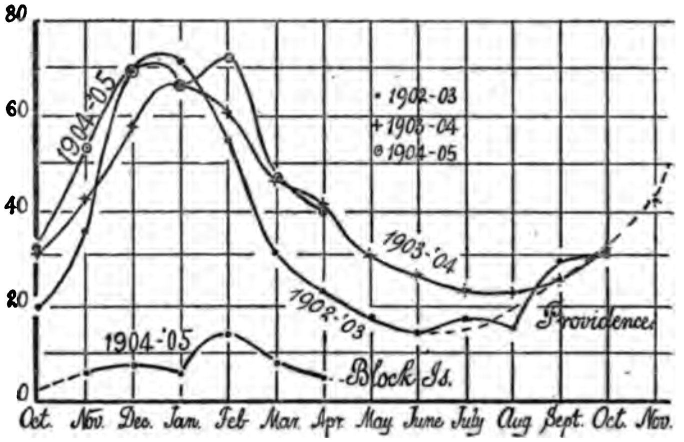

FIG. 103.—Average monthly nucleations at Providence in thousands per cubic centimeter from October, 1902, to May, 1905. The lower curve shows corresponding results taken at Block Island.

87. Average monthly nucleations.—The properties of the new curve just referred to appear more obviously if the monthly averages are drawn in their dependence on time, as is done in table 62 and in figure 103. In the latter the data for 1902–3 and 1903–4 are included, the points of the different curves being suitably distinguished. The tendency to reach a maximum in December appears in all these curves, but the curve for 1904–5 departs from them in its pronounced march toward the duplicate maximum in February, after which, however, there is clear agreement between the 1903–4 and 1904–5 curves, neither of which falls to the low nucleations for March, April, etc., in 1902–3.

The chart, moreover, contains the average monthly nucleations observed by Mr. Pierce at Block Island. It is interesting to note that the general march here is the same as at Providence, a definite tendency toward a maximum in December and then a relatively enormous maximum in February, from which there is slow descent to the summer nucleation which would be nearly vanishing. To accentuate these relations, figure 104 has been drawn, in which the nucleations at Providence and at Block Island are given in ten thousands and in thousands of nuclei per cubic centimeter, respectively. The same February disturbance is thus superimposed on the high local nucleations due to combustion, etc., at Providence, which exists in comparative freedom from local discrepancy at Block Island. It is hard to resist the conclusion that so marked an interference with the usual distribution of nucleation can result from local or terrestrial causes. Thus, the average March nucleation at Block Island exceeds the December nucleation, while the April nucleation is nearly as high as the January nucleation.

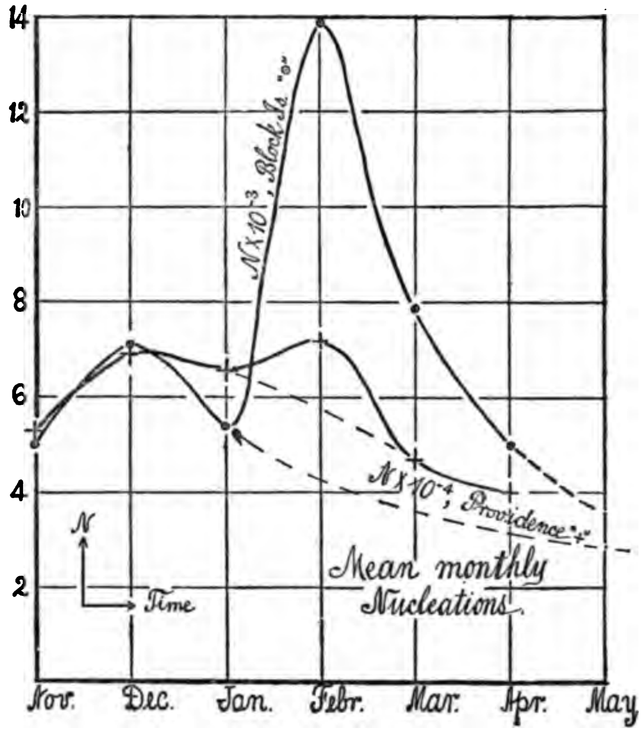

FIG. 104.—Average monthly nucleations from November, 1904, to May, 1905, at Providence in ten thousands per cubic centimeter, and at Block Island in thousands per cubic centimeter, showing the probable run of the curves in the absence of the February maximum and the coincidence of the maxima and the minima.

Mr. Pierce has compiled the following summary of monthly averages of vapor pressure, temperature, barometer, sunshine, rainfall, etc. Of these the data for temperature and precipitation are most important. The latter was, in fact, a minimum (0.05) in February, but differing in value but slightly from November (0.06) and March (0.07). It is not probable that any effect was thus produced. Similarly the temperature is a minimum in February (25°), differing, however, by but 3° from January (28°), while the nucleation is more than doubled (14/5.4). Moreover, the December maximum of nucleation does not exist for temperature. It seems, therefore, equally improbable that for so small a difference of temperature, so enormous differences in general combustion (if this were the cause) could be evoked, and more likely that both the temperature minimum and the nucleation are different effects of some other common cause.

TABLE 63.—Meteorological Data.

Average values of—	1904.		1905.		
	Nov. 26–30.	Dec. 1–22, 30, 31.	January.	February.	March.
Vapor pressure	159	128	116	96	166
Temperature	38	30	28	25	32
Relative humidity	68	76	73	70	81
Sunshine	3.3	2.7	6.4	6.8	7.8
Precipitation	.06	.09	.08	.05	.07
Range of temperature variation	13.0	11.4	11.7	12.1	10.8
Wind velocity (hours)	22.3	22.9	24.2	22.2	15.5
NE. to S.	.00	.23	.19	.18	.37
SW. to N.	1.0	.78	.81	.82	.63
Cloudiness	.46	.70	.44	.40	.47

There does not, therefore, seem to be in the weather conditions in February any reason for so marked a change in the nucleation. Neither is the temperature low enough nor the rains sufficiently infrequent to account for the accumulation of nucleation observed.

These facts also appear in the ratios in table 62, showing that whereas the Providence nucleation was 10 to 12 times larger in December and January than the Block Island nucleations, the ratios fall off to but 5 in February, from which low datum they slowly recuperate.

88. Conclusion.—While the Block Island observations have therefore proved that much the greater part of the nucleations observed at Providence is of local origin, it has not proved that all of it is of this character. In fact, there remains a residue of 5 to 10 per cent of the observed nucleation in question, which is still present and undergoing phenomenal variations in places remote from the habitations of man.

Moreover, the arithmetical character of the fluctuation of nucleation in the lapse of time is the same at the two stations, however widely the geometrical character may differ. It is thus probable that in both cases there is superimposed on a local nucleation (large at Providence and vanishing at Block Island), fairly constant for long periods during the winter months, a specific effect, due to causes which are certainly not local. In fact, the same character of variations was observed at the two stations in spite of the fact that the air under examination is necessarily quite different.

The outstanding February maximum may be a distant land effect, due to artificial causes, chiefly combustion, and nearly uniformly distributed over the whole inhabited territory; but from the suddenness of its appearance, its pronounced character, and the extended occurrence as instanced at both stations, one is tempted to regard it as an actual invasion of the atmosphere on the part of some external radiation or nuclei-producing agency.

It would have been better if the pressure difference at the station, where the air is relatively pure had been more nearly equal to the fog limit of dust-free air ($\delta p=22$), *i. e.*, decidedly above the fog limit for ionized air ($\delta p=19$); but at the outset it was thought wise to avoid this complication. In such a case the coronas reached by the present method ($\delta p=17$) would all have been obtained; but in the comparative absence of ordinary nuclei, a response from ionized material might be anticipated. The treatment of filtered air, however, for purposes like the present or the interpretation of the results obtained is an extremely precarious matter, as I shall point out in a subsequent paper. Meanwhile we may note that the curve of average monthly nucleations is apt to show a maximum and minimum, respectively, at about the time of the winter and summer solstices, and that any definite fluctuation from this curve is due to causes which are at least nonlocal in character.

CHAPTER VI.

SUMMARY AND CONCLUSIONS.

89. Introductory.—Researches have been made both with respect to the ordinary relatively large or dust-like nuclei contained, *i. e.*, such as will not pass through the cotton filter, and with respect to the nuclei much smaller in size and probably belonging to the molecular system of air, as they are inseparable from it by filtration. Nuclei of the former class are usually (though not necessarily) foreign in character. Those of the latter class may also be so; but as they are demonstrably small, even when compared with the ions, and are speedily reëstablished if withdrawn from the air, their true nature may be that of colloidal air molecules. Being present in thousands and millions per cubic centimeter, in proportion as the order of molecular size is approached, they are not to be identified with the ions for this reason alone, as the number of the latter is insignificant in comparison. From what has been stated, colloidal air molecules (nuclei) can not be regarded as stable chemical bodies, since, if precipitated by condensation, they are immediately reproduced in the medium of moist air out of which the precipitation took place. They can not be brought to vanish in long periods of decay. In fact, the coronas of filtered air attain their maximum size after long waiting; for in this way all other larger nuclei which may incidentally be present are brought to vanish.

Hence one must conclude that the nuclei which pass the filter are present in a definite ratio dependent on the conditions of chemical equilibrium of the most general kind.* As a rule, for each such nucleus which decays, another is generated in the nonenergized dust-free air in question, leaving the nuclear status constant.

If we, furthermore, suppose that the formation of a nucleus is accompanied by the expulsion or the absorption of a corpuscle representing the ionization, it is clear that a very high degree of nucleation may be compatible with a very low order of ionization, such as is the case with ordinary dust-free air; for the concomitant ionization represents the degree to which a decaying nucleus is not at once replaced by a newly generated nucleus of the same type, and *vice versa*. In other words, the ionization present represents the oscillation of the system

*Including the effect of internal and possibly external radiations.

around its state of chemical equilibrium, the sense of the departure being in the long run as frequently positive as negative.

These are the chief features of the hypothesis by which I have been guided in my work. It will now be desirable to present an outline of such facts bearing on the whole question as occur in my own researches. To obtain sufficiently varied conditions it will manifestly be necessary to produce nuclei in the condensation chamber (briefly called the fog chamber) itself, without introducing foreign material. This may be done by aid of the X-rays or the beta and gamma rays of radium, preferably to the exclusion of the emanation and even of the alpha rays. Changes of nucleation so obtained may be regarded as arising out of the dust-free contents of the fog chamber.

90. Notation.—The nucleations, N, referred to in these paragraphs, are computed from the angular radius, ϕ, of the corona seen in the fog chamber and the quantity of water precipitated in the given exhaustion, in the way detailed in my report to the Smithsonian Institution (1905). In the figures, which for brevity are referred to in place of the tables, D denotes the distance of the X-ray bulb or the radium tube (of thin aluminum, hermetically sealed) from the near end of the fog chamber. *Exp.* is the time of exposure in minutes to the radiation stated; Lp, the lapse of time after exposure to the radiation ceases, or the time during which the nuclei under observation are left without interference. The abscissas (unless otherwise specified) frequently indicate the number of an observation; *i. e.*, they are merely distributive and represent the character of successive phenomena to the eye. The fog chambers used were sometimes rectangular boxes of wood impregnated with wax and provided with plate-glass windows; at other times clear glass cylinders, 15 cm. long and 15 cm. or more in diameter. The latter case insures greater freedom from traces of leakage, but coronal aperture, 2ϕ, must be measured parallel to the axis of the cylinder. Usually the chord, s, for a radius of 30 cm. will be given, so that $2 \sin \phi = s/30$.

Exhaustions are preferably made at a pressure difference (δp) between the outside and inside of the fog chamber, just below the point (to be called *fog limit* δp_0) at which dust-free nonenergized saturated air condenses without foreign nuclei. δp_0 depends on the particular apparatus used.

91. Fleeting nuclei—Ions.—Let the X-radiation to which the dust-free air is exposed be relatively weak, so that the density of ionization may remain below a certain critical value. The nuclei observed on condensation are then very small, and they require a high order of exhaustion, approaching but always below the fog limit of non-energized air. They are usually instantaneously generated (within a second) by the radiation, so that their number is definite independent of the time of exposure. They decay in a few seconds after the radiation ceases, *i. e.*, roughly, to one-half their number in 2 seconds to one-fifth in 20 seconds, in the usual way. (*Cf.* Chapter III, figs. 42, 43.) I fancy that these nuclei are what most physicists would call ions; but nevertheless the particles are not of a size, the dimensions depending on the intensity of the penetrating radiation to which they are usually due, and they pass continuously into the persistent nuclei, as shown in the next paragraph, where decay of ionization and of nucleation are very different things. They are abundantly produced by the γ-rays, which, though weak ionizers, become from this point of view strong nucleators (section 16). Finally (section 6) they are stable on solution. The case seems rather to be one in which the rate of decay exceeds the rate of production. The following is an example of data bearing on this case, N being the number of nuclei caught per cubic centimeter of the dust-free air at normal pressure. The anticathode is at a distance from the fog chamber and the exhaustion carried to the verge of the fog limit of dust-free air.

Time of exposure (rays on), ...	0	5	15	30	60	120 secs.
$N\times 10^{-3}$, ...	*1.6	74	74	—	74	—
Time after exposure (rays off), ...	0	5	15	30	60	120 secs.
$N\times 10^{-3}$, ...	92	30	23	18	10	4

The two series refer respectively to generation and to decay.†

If N is expressed in thousands of nuclei per cubic centimeter, and time, t, reckoned in seconds, and if $1/N=a+bt$, so the $dN/dt=-bN^2$, the datum $b=0.002$ reproduces the results satisfactorily, while a simple exponential law will not do so. The decay is of the kind characterizing mutual action between ions. In figures 42, 44, Chapter III, computed data are distinguished by crosses.

92. Fog limits of fleeting nuclei.—The mean increment of nucleation, δN, per centimeter of increment of pressure difference, δp, varies very rapidly as compared with the fog limit, δp, so long as the reference is to the interval of large variation. It makes no difference by what radiation the nucleation is produced (X-rays or other radiation), $\delta N/\delta(\delta p)$ is rapidly larger as the intensity of ionization is greater, while δp_0 becomse slowly smaller within the interval in question (Chapter III, figs. 49, 63 to 68). Below the fog limit of air and

* Fog limit of dust-free air just exceeded.

† Including loss by diffusion or other time loss.

slightly above the fog limit of the ionized medium the following data are typical. N_{21} shows the number of nuclei caught when $\delta p = 21$ cm., which lies within the pressure interval stated.

	$D =$	$\delta p_0 =$	$10^{-3} N_{21} =$	$10^{-3}\delta N/\delta(\delta p) =$
Radium (10,000 ×)	200	(20.5)	1	4
	50	20.4	5	9
	25	20.3	10	(14)
	0	20.1	18	20
X-rays	200	20.3	10	16
	50	(20.1)	22	(24)
	10	(19.7)	45	(33)
	5	19.6	50	36

The full N curves are best given graphically. Data for the radium at $D = 100$–200 cm. are scarcely distinguishable from air (fig. 68, Chapter III) except near the fog limit; for radium at $D = 10$–25 cm. they lie close together, above the former and below the data for $D = 0$. With these, the X-ray effects at $D = 10$–50 are in sequence. Thus there is general continuity between the air curves, the radium curves, and the X-ray curves. As a whole, the curves for D and δp are doubly inflected; relatively large (efficient) nuclei are rapidly fewer in number as δp decreases; relatively small nuclei are also rapidly fewer in number as δp increases. Nevertheless the efficient nuclei of intermediate dimensions are of all sizes, while this size tends to become more uniform as the ionization is greater, *i. e.*, the slopes of the curves become steeper. Gradation is accentuated for the case of weak ionization. The case of nonionized air is shown in figs. 45, 46, Chapter III.

The efficiency here referred to depends not merely on the apparatus (suddenness of exhaustion), but in particular on the degree to which larger nuclei are present, remembering that all the nuclei in question are produced in dust-free air. As the nuclei are essentially graded in size, the larger soon capture all the available moisture to the exclusion of the smaller, and the coronal diameter ceases to increase with δp. The question will be specifically treated elsewhere.

93. Persistent nuclei.—If the X-ray bulb is approached nearer the fog chamber, or if a more efficient bulb is used, so that the density of the ionization within the fog chamber is sufficiently increased, the rate of production of nuclei will eventually exceed the rate of decay. (See figs. 50, 51, 67, 84, Chapter III.) Under these conditions there is not merely an increase of number in the lapse of the time of exposure to the radiation, but essentially an increase of size, *i. e.*, the nuclei grow indefinitely. They are now persistent for hours after the radiation ceases. The number, N, per cubic centimeter increases, therefore, in marked degree and at an accelerated rate with the time of exposure, certainly for 10 minutes or more, barring the invariable loss of efficiency of the X-ray bulb. These nuclei are large, requiring very little supersaturation for condensation, and are much like any ordinary nuclei. They are pronouncedly of all sizes, and the initial coronas are apt to be distorted and stratified beyond recognition. Whirling rains (section 94) and fog accompany the first condensation. While small nuclei occur throughout the chamber, the end near the bulb is at first the seat of growth, which gradually extends to the other end, as I have shown elsewhere.* The following two series of data, showing the generation and decay of nuclei in question, may be cited as illustrations. The pressure difference, $\delta p = 20$ cm., is much below the fog limit for dust-free air, in the given apparatus.

Time of exposure 0	5	10	20	60	120	180 sec.	
$N \times 10^{-3}$.................. 0	2	11	10	80	†(100)	†(500)	
Time after exposure..	0	36	85	240 minutes.			
$N \times 10^{-3}$..................	(100)	36	20	Vanishing.			

Hence there is a decay of one-half in 10 minutes and of one-fifth in 80 minutes, or the degree of persistence is 200 to 300 times larger than in the first paragraph. The data indicate, moreover, that both of these extreme types of nuclei and all intermediate types now occur together, as may be tested by changing the pressure difference, δp, on exhaustion. (*Cf.* fig. 51, Chapter III, for $\delta p = 25$.) Intermediate rates of generation and decay may be obtained by moving the bulb nearer to or farther from the end of the fog chamber. Finally, the rates at which the nuclei and the ionization severally decay, between which it would be difficult to distinguish in the case of the very fleeting nuclei, stand in sharp contrast with the persistence of the nuclei of the present paragraph.

If N be expressed in thousands of nuclei per cubic centimeter, and time of decay, t, in seconds, the equation $1/N = a + bt$ (for which there is here but little justification) shows that $b = 0.000013$, over 200 times smaller than in section 91. (*Cf.* fig. 50, Chapter III.)

First exhaustion data of the generation of persistent nuclei are difficult to obtain, because the coronas soon become heavy fogs, distorted beyond recognition, and the fog limits variable over wide limits, often approaching vanishing smallness. The number of persistent nuclei generated varies with the time of exposure at an accelerated rate, as if the nuclei themselves assisted in the generation. (*Cf.* section 100; also fig. 84, Chapter III.) For instance, at $\delta p = 19.7$ cm., after the times of exposure, 1, 2, 3 minutes, the nucleations were $N = 10^{-3}$ 22, 77, (120), respectively.

* American Journ. Sci., XIX, 175.

† Computed from second exhaustion, after subsidence of the dense fogs of first.

94. Fleeting nuclei become persistent on solution—Origin of rain.— Let the fog chamber be exposed to radiation for a few seconds and thereafter exhausted ($\delta p = 25$) as usual. Closing the exhaustion cock and allowing only time enough to measure the first corona, let the influx cock be opened and the fog chamber be refilled with dust-free air. The (primary) corona observed is thus dispelled before much subsidence of fog particles can take place, though the rain will naturally drop out. If the fog chamber is now left without interference (the radiation having been cut off immediately after the first exhaustion) for one or more minutes or longer, a second exhaustion to the stated limits will show a large (secondary) corona relatively to the primary corona. In other words, relatively many of the fleeting nuclei or ions caught in the first fog have persisted, whereas without condensation they would have vanished at once after the radiation was cut off. (*Cf.* figs. 56–59, Chapter III.) The following is an example of data bearing on this point, t denoting the time elapsed from the evaporation of the first corona to the precipitation of the second, N_1 the number of nuclei in the first, and N_2 the number in the second corona:

	Secs.	Secs.	Secs.
$t =$	60	120	300
$N_1 \times 10^{-3} =$	53	27	53
$N_2 \times 10^{-3} =$	16	7	15

The experiments are complicated by the variable X-ray bulb; but it is obvious that while all the nuclei would have vanished in a few seconds without condensation, about one-fourth (in other experiments more) persist indefinitely, if reëvaporated after condensation from fog particles.

This result has an important bearing on the whole phenomenon of condensation and nuclei. Clearly the latter, after the evaporation specified, becomes solutional or water nuclei, in which the original fleeting nucleus or ion behaves as a solute. The decreased vapor pressure due to solution eventually compensates the increased vapor pressure due to curvature, after which, at a definite radius, evaporation ceases and a water nucleus results. Such a nucleus, however small, must be large in comparison with the dissolved ion. Hence, on condensation, the water nuclei will capture the moisture soonest and grow largest. Now, in any exhaustion about one-eighth of the fog particles, *i. e.*, those which are smallest and whose nuclei have been caught at the end of the exhaustion, regularly evaporate into the larger particles to a residue of water nuclei. These are, then, the first to be caught in a succeeding exhaustion. This is the explanation of the *rain* which not only accompanies all coronas in dust-free air, but is often dense. It is also an explanation of those indefinite alternations of large and small coronas (periodicity).

Further experiments in the wooden fog chamber showed that 25 to 50 per cent of the fleeting nuclei could be caught and made stable on solution. The mean datum of all results, irrespective of the time interval (the effect of which within a few minutes is probably inappreciable), is a preservation of 39 per cent on reëvaporation of the originally fleeting nuclei from the fog particles condensed on them. In the absence of subsidence of fog (which can not here be allowed for), the result would be larger. In the glass fog chamber, which could be made rigorously free from leakage, but in which the subsidence loss was greater, 20 per cent persisted, while all but 2 to 5 per cent were lost in one minute in the absence of solution. Persistence in the 1 to 3 minutes following evaporation was not appreciably different, indicating long periods of decay. (*Cf.* fig. 60, Chapter III.)

95. Solutional enlargement of the nuclei of dust-free air.—The most interesting case observed is the marked decrement of the fog limit of dust-free air producible by solution of the nuclei. (*Cf.* figs. 61, 62, Chapter III.) Let the first exhaustion be made decidedly above the fog limit, $\delta p = 22$ cm. (say here at $\delta p = 23$ cm.), to obtain a corona of appreciable size. On evaporating the fog particle, let the second exhaustion be made decidedly below the fog limit (say at $\delta p = 21$ cm.). A large corona, which would otherwise be quite absent, will be observed. Within 3 minutes about 25 per cent of the nuclei are found to persist After 10 minutes not more than 50 per cent were left. Whether, without solution, air nuclei are possibly evanescent, and therefore maintained by some penetrating radiation, remains to be seen. It should be recalled that the nuclei in question are small, even as compared with ions.

96. Water nuclei—Solutional nuclei in general.—Apart from the functions suggested in sections 94 and 98, it is clear that the water nucleus must play an important part throughout all phenomena in nucleation. It seems probable that immediately after exhaustion precipitation takes place on all nuclei, large and small, within the scope of the pressure difference applied. The smaller fog particles then at once begin to evaporate until the decrement of vapor pressure, due to increasing concentration of the solution, is equivalent to the increment of vapor pressure due to decreasing size, whereupon evaporation ceases. This is the condition of persistence of a water nucleus, the ultimate size of which depends on the original strength of the solution partially evaporated. Clearly the water nucleus is always larger than the original nucleus which it holds in solution.

Phenomena of the present kind may be examined by identically agitating solutions of different bodies in different solvents and of different strengths, beginning with the pure solvent. This may be water or any other volatile liquid. The number of nuclei obtained, *cæt. par.*, varies both with the solvent and the solute. Thus on shaking 1 per cent solutions identically and computing the number of nuclei, N, from the coronas observed in each case the following data were found: Pure water, $N=130$; organic bodies dissolved in water (sucrose, glucose, glycerin, urea, etc.), $N=600$; mineral salts dissolved in water (nitrates, chlorides, sulphates, etc.), $N=1{,}300$; naphthalene dissolved in benzol, $N=3{,}500$; paraffin in benzol, $N=5{,}000$. A definite demarcation of groups is thus apparent, but it is difficult to even conjecture an explanation.

If the solvent is pure, the nuclei produced by shaking are excessively fleeting, a result attributable to their relatively small size. As the concentration increases for a given solvent, persistence increases with the number of nuclei produced.

If the absorption per second takes place at the walls of the vessel as the first power of the number of nuclei present, the following constants (k) show the character of the phenomena:

Pure water			$k=5$–10
Inorganic saline solutions	1	per cent	$k=0.05$
	0.01	per cent	$k=0.08$
	0.0001	per cent	$k=2$
Neutral organic solutes in water,	1	per cent	$k=0.2$
	0.01	per cent	$k=0.6$
Neutral liquid organic solutes in water	1	per cent	$k=1.2$
	0.01	per cent	$k=2.4$
Solid hydrocarbons in liquid hydrocarbons,	1	per cent	$k=0.02$ to 0.04

When the solvent is a hydrocarbon, etc., the fog particles are relatively large as compared with the water particles (*cæt. par.*). Hence the coronas remain normal (white-centered and showing the usual diffraction pattern) even when the nuclei are present in millions per cubic centimeter. These coronas, moreover, are intensely brilliant, and but for the difficulty in keeping the heavy vapors saturated, they would offer exceptionally good conditions for the measurement of nucleations. Again, the exhaustion method is available for investigating the diffusion of the heavy vapors into nucleated air. Finally, sulphuric-acid nuclei, sulphur and sulphide nuclei (oxidizable to sulphates) are probably a special class of water nuclei which are stable because they contain an intensely hygroscopic solute.

97. Alternations of large and small coronas—Periodic distributions of efficient nuclei in dust-free air.—The coronas in question may be distinguished as superior and inferior coronas. They are obtained in successive exhaustions of dust-free air, under conditions of experiment which are quite identical, filtered air being introduced in the periods between the exhaustions, after all the fog particles have subsided. The efficient nuclei are therefore present in large and small number, alternately, usually in the ratio of about 8 to 1. Figures 14 and 15, Chapter II, give an example of the changes of angular coronal diameter, s, in the successive observations with dust-free air enumerated by the abscissas. The pressure difference is $\delta p = 31$ cm. and the time between the exhaustions 2 minutes. Twenty exhaustions are recorded, but the experiment might have been prolonged indefinitely. In figure 17, Chapter II, there are 3-minute periods between the exhaustions. In figure 18 the periods are 5 minutes in length, but the phenomenon here vanishes. All the graphs show that relatively high inferior coronas (h) are followed by relatively low (l) superior coronas, and low inferior coronas are followed by relatively high superior coronas; furthermore, that coronas of mean aperture are followed by coronas of the same kind, so that the periodicity ceases, as seen in figures 16 and 18 of Chapter II. In figure 16 alternations and steady aperture were obtained under otherwise like conditions. In figure 26 the same phenomenon is exhibited in case of dust-free air energized by weak radium. The ordinates here show the number of nuclei per cubic centimeter, so that the sweep of the alternations is more striking.

An explanation of these phenomena may be given (sections 96, 98) in terms of the occurrence of water nuclei produced by the evaporation of the small fog particles to a size at which solutional decrement of vapor pressure balances the increment due to increased curvature. In figures 14 and 15, Chapter II, the average inferior nucleations of dust-free air are about 12,000, the average superior nucleations over 90,000, so that explanations in terms of negative and positive ions are out of the question.

To precipitate nuclei which, as is usual, are more or less graded in size, in a single exhaustion, must be generally impossible for similar reasons. While temperature after exhaustion approaches its original isothermal value, the small particles caught at the end of the exhaustion to the amount of about 10 per cent of the total number evaporate to the water nuclei stage, to be precipitated in the next exhaustion. This evaporation probably accounts for the permanence of coronas throughout the period of subsidence of fog particles, during the early stages of which temperature rapidly increases.

98. Cause of periodicity.—In cases of large and small coronas, whether the persistence be attributed to electrical potential or to solution, a water nucleus is always in question. Small fog particles are caught on small nuclei near the limit of exhaustion and these evaporate and become the water nuclei available for the next exhaustion. In general, there are three groups of nuclei (x, y, z) concerned in any exhaustion: A group, x, of water nuclei form the preceding exhaustion; a group, z, which will evaporate to make the water nuclei of the succeeding exhaustion; finally, the group y, comprising nuclei adapted to become the efficient nuclei of the exhaustion in question.

In case of periodicity the successive exhaustions follow the scheme—

Exhaustion 1	—	y_1	z_1	Superior corona on y_1
2	$x_2=z_1$	—	$z_2=0$	Inferior corona on z_1
3	$x_3=z_2=0$	y_2+y_3	z_3	Superior corona on y_2+y_3
4	$x_4=z_3$	—	$z_4=0$	Inferior corona on z_3
5	$x_5=z_4=0$	y_4+y_5	z_5	Superior corona on y_4+y_5

All the details observed with alternations are thus explained. In view of the rapidity of decay, the corona will be formed on the saturation value of y_n+y_{n+1}.

99. Persistence in general.—This may reasonably be ascribed to the formation of water nuclei, a point of view carried out in my memoir on the structure of the nucleus (Smithsonian Contributions, No. 1373, vol. 29, 1903), but much enhanced by the data of the present investigation. The heavy rains accompanying condensation in case of the persistent X-ray nuclei are attributable to spontaneous condensation without supersaturation, the nucleus acting under intense X-radiation like a hygroscopic solute. The same result may follow the action of ultraviolet light, as it certainly must result from the presence of phosphorus and of sulphuric-acid nuclei.

100. Secondary generation.—This is a curious phenomenon, showing that the decaying persistent nucleus produced by the X-rays is apparently radio-active, or that the walls of the fog chamber are so, or else that the large nuclei, if left without interference, break into a number (on the average about three) of smaller nuclei, whereby the nucleation is actually increased in the lapse of time after exposure. In other words, if the nucleation is observed without cutting off the radiation in one case, and if in the second case the nucleation identically produced is observed at a stated time after the radiation has ceased, the number in the latter case (anomalously enough) is in excess. (*Cf.* fig. 70-76, Chapter III.) The following examples make this clear, the X-ray bulb being 5 cm. from the fog chamber, and the exhaustion carried to $\delta p = 20$ cm. These data are computed from the second exhaustions, as the first show the densely stratified fogs unavailable for measurement.

Rays on..........	2	2	2	2	2	2	2	2	2 minutes.
Rays off..........	0	4	0	4	0	2	0	20	0 minutes.
$N \times 10^{-3}$	20	52	20	32	25	30	13	34	30

With the bulb at different distances from the fog chamber, the following data admit of the same interpretation (figs. 74, 76):

Distance, $D=$	5	10	15	5	10	15 cm.
Rays on	2	2	2	2	2	2 minutes.
Rays off......	0	0	0	2	2	2 minutes.
$N \times 10^{-3}$......	22	3	1	58	9	1

The phenomenon vanishes when the radiation is too weak to produce persistent nuclei, therefore, either when the bulb loses efficiency or when it is too far from the fog chamber.

101. Space surrounding the X-ray tube a plenum of radiations.— While the phosphorescent, photographic, and electric effects of X-radiation decrease rapidly with the distance, D, from the tube, the nucleating effect (N, nuclei generated per cubic centimeter, instantly) is nearly constant over relatively enormous distances.* (*Cf.* fig. 69, Chapter III.) Thus to give two examples among many ($\delta p = 25$ cm.):

$D=$........	6	200	600	6	200	600 cm.
$N \times 10^{-3}$....	88	83	83	79	79	79

The laws of inverse squares would predicate a reduction of 10,000 to 1 between these limits; and, in fact, at 6 cm. the phosphorescent screen is intensely luminous, at 200 cm. very dim, at 600 cm. quite dark, as in the case of any ordinary illumination. The leaves of an electroscope within a glass bell jar collapse in a time which is directly as the square of the distance from the energized X-ray bulb. The result obtained with nuclei is astonishing; the nuclei-producing radiation would, at first sight, seem to be of an extremely penetrating kind, akin to the gamma rays of radium, and distinct from the ordinary phosphorescence-producing X-rays. This impression is accentuated by the fact that the radiation can not be stopped by lead screens many centimeters in thickness, placed between bulb and fog chamber. (*Cf.* figs. 79, 81, 82, 83, Chapter III.) The following are typical examples, in which the distance between the lead plates screening the fog chamber and the X-ray tube is $D=600$ and 200 cm., respectively. N

* Supposing that the fog chamber is not inclosed in impervious metal. In the latter case, with the lead covering open toward the X-ray bulb only, there is constancy of N within 20 per cent over 6 meters.

shows the number of nuclei instantly generated behind the lead plates in the two cases.

Thickness of lead screen.....	0	0.14	0.28	0.56	0.84	1.12	0 cm.
$D=600$ cm. $N\times 10^{-3}$......	67	28	28	31	29	31	76
$D=200$ cm. $N\times 10^{-3}$......	79	44	48	41	—	44	70

Again, the X-ray bulb apparently emits this radiation forward as well as rearward, as if the thin anticathode were quite pervious. I found, for instance, for the radiation of the anticathode at 6 meters from the fog chamber—

From the front face (tube directed), $N\times 10^{-3}=42$
From the rear face (tube reversed), $N\times 10^{-3}=35$

or 81 per cent of the former apparently issues from the rear face (fig. 80, Chapter III). Even the reversal of the current does not stop the radiation, for about 16 per cent of the normal intensity is still radiated when the concave mirror is made the anode (fig. 80, Chapter III).

The total efficient radiation may be reduced to a limit by lead screens a few millimeters in thickness, or less; thereafter it can not be further reduced by lead screens many centimeters in thickness. For instance, when the radiation comes from 600 cm., a single lead plate (thickness 0.14 cm.) is more than sufficient to reduce the effective radiation to a minimum, which amounts to (somewhat less than) one-half of the total intensity, at least when estimated in terms, of the number of nuclei produced. (Figs. 81, 83, Chapter III.) If the nucelation comes from 200 cm., one plate has the same effect, even though a thickness of 400 cm. of air has been removed. The thickness, 0.14 cm., is more than enough to reduce the radiation to the limit in question. This again amounts to a little more than one-half the total intensity. (Fig. 82, Chapter III.) At a distance of 5 cm. no more plates may be needed; but the conditions are now too complicated to be described here, chiefly because persistent nuclei are producible. Moreover, 80 per cent of the total intensity may ultimately escape absorption. Thus the rays from different distances behave alike for the more pervious media and in relation to very dense screens. (Fig. 83, Chapter III.)

102. Lead-cased fog chamber.—To interpret these surprising results it will be necessary to surround the fog chamber with a casket of lead, having a lid on the side fronting the X-ray bulb; for even though the lead plates above may efficiently cut off the primary rays, they would leave the secondary radiation free to enter laterally through the broadsides of the fog chamber. When this was done the results reduced the penetrability of lead to a more reasonable figure, as may be seen from the following example of results when the distance between bulb and fog chamber was 2 meters:

Thickness of lead penetrated=	0	0.14	0.28	0.42 cm.
$N \times 10^{-3}$	77	10	7	5

i. e., 14, 9, and 7 per cent of the total intensity passes one, two, and three plates, respectively. (Figs. 77, 78, Chapter III.) A glass plate, 7 mm. thick, and an iron plate, 0.5 mm. thick, allowed about 90 per cent to pass; when the casket was left open, and the lead plate placed near the bulb, 17 per cent of the total radiation was effective, the excess being of secondary origin. The passage through a plate of tinned iron (*cf.* figs. 85, 86, Chapter III) may be observed for a bulb 6 meters distant, as follows:

Thickness of plate	0	0.05	0.10	0.20 cm.
$N \times 10^{-3}$	36	28	11	7

It follows, then, that in the above examples (101) nearly one-half of the total radiation was derived from secondary sources, since the primary radiation was certainly stopped off to within 10 per cent by the lead plates. To the eye of the fog chamber, therefore, the walls of the room are aglow with radiation, and no matter in what position the bulb may be placed (observationally from 6 cm. to 6 m. between bulb and chamber), the X-illumination, as derived from primary and secondary sources, is constant everywhere. It is to be understood that the X-illumination here referred to may be corpuscular. In fact, so far as I see, the primary and secondary radiation here in question may be identical; for the corpuscles may come from the circumambient air molecules shattered by the shock of gamma rays.

The fog chamber, if open at the end toward the bulb, shows the same total intensity; but in such a case the inner walls of the casket, etc., become the source of secondary rays.

The behavior of the wooden fog chamber in relation to rays coming from different distances being such as if the circumambient medium were equally energized with something recalling the character of galvanic polarization throughout, the following mean data are designed to throw further light upon this behavior (fig. 69, Chapter III).

Fog chamber	$D=$ 6	50	200	600 cm.
Wood, lead-cased	$10^{-3} N=$ 50		50	38
Glass, walls 0.3 cm., bottom 1 cm. thick	{70 55		41 34	22 14
Glass, cased in close-fitting lead tube, prolonged 50 cm. toward bulb	—	*52	25	12

Media pervious with difficulty eliminate the secondary radiation entering the broadsides of the fog chamber, and to close the end toward the bulb is to eliminate nearly all the rays (figs. 77, 78, Chapter III); but if this is open, the number of nuclei instantly generated decreases much more slowly than the first power of distance. The fact that to the very pervious wooden fog chamber the medium within a sphere of at least 6 meters in radius remains almost equally energized throughout remains a result of importance.

103. Possibility of two kinds of radiation from the X-ray tube.—It has been shown that for very short exposures (sections 101 and 102) the nucleation is the same, whether the bulb is placed at 6 cm. or 6 m. from the fog chamber. But only in the former case ($D=6$ cm.) is the effect cumulative; only for very short distances will persistent or very large nuclei appear if the exposure is prolonged several minutes. I have, therefore, suspected that the radiation from the X-ray bulb is twofold in character; that the instantaneous effect (fleeting nuclei) is due to a gamma-like ray, quick moving enough to penetrate several millimeters of iron plate appreciably even for $D=6$ meters; furthermore, that the cumulative effect (persistent nuclei) is due to X-light, properly so called, which produces the usual effects subject to the laws of inverse squares; but it is noteworthy that while the penetration of X-rays is relatively small, and the distance effect negligible (section 101), they are both large for the radiation from radium (section 104).

104. Nucleation due to gamma rays.—To what extent nucleation is producible by gamma rays may be tested by radium inclosed in a thick chamber of lead. The results are strikingly comfirmatory. (Figs. 87 to 89, Chapter III). For instance, in case of 10 mg. of radium (10,000×) inclosed in a hermetically sealed alumimum tube and placed outside but close to the end of the fog chamber (bottom nearly 1 cm. thick, walls 0.3 cm. thick), the data were (fig. 89, Chapter III):

Radium in sealed aluminum tube......	$10^{-3}N=27$	Transmission 100
Radium in lead tube 0.5 cm. thick	23	85
Radium in lead tube 1 cm. thick.......	18	69

The nuclei are thus very largely due to this extremely penetrating radiation. By using lead tubes, capped and not capped, 30 cm. and 60 cm. long, and placed parallel to the fog chamber and in contact with its sides, no evidence of secondary radiation was discernible, the effective radiation passing through the lead walls as specified.

In comparison with the abundant nucleation after the penetration specified, the decrease of nucleation observed when the tube is at different distances, D, from the fog chamber is remarkably large. For example (fig. 90, Chapter III),

$$\begin{array}{rcccccc} D= & 0 & 10 & 30 & 50 & 100 & 200\text{ cm.} \\ N\times 10^{-3}= & 30 & 13 & 8 & 5 & 3 & 2 \end{array}$$

* Through 0.14 cm. of lead $10^{-3}N=3$; through 0.05 cm. of iron $10^{-3}N=44$.

If measurement be made from the line of sight (10 cm. from the ends of the fog chamber), the nucleation decreases less rapidly than the first power of distance. Hence, whereas the distance effect in case of X-rays is small, it is very large in case of radium. On the other hand, rays from radium show remarkable nucleating power after penetrating many centimeters of lead, whereas the nucleating power of the X-rays after such penetration is relatively negligible. (Figs. 69 and 78, 89 and 90, Chapter III.)

105. Distribution of nucleation within the fog chamber—Radium.— Finally, when the rays have once entered the fog chamber, the nucleation along the axis seems nearly uniform. Measurements are difficult; but while the nucleation decreases nearly to one-fourth when the radium is placed on the outside of the fog chamber, 40 cm. axially from the end, the coronas along 40 cm. within the fog chamber are nearly of the same aperture for any given position of the radium tube.

106. Distribution of nucleation within the fog chamber—X-rays.— Obviously when the X-ray bulb is at a distance from the fog chamber and the nuclei fleeting, they will be uniformly distributed within the chamber, being everywhere at saturation density for the given intensity of radiation.

The conditions are far different, however, when the bulb, as in figure 1, Chapter I, is near the chamber and the nuclei persistent. In such a case, if we distinguish between the A and the B sides of the fog chamber (where A is nearer the bulb), and if we use a pressure difference, δp, decidedly below the fog limit, δp_0, of dust-free air, the nuclei within the given range of condensation are for short times of exposure found on the A side only. The coronas are relatively small in size, roundish, decreasing in aperture to a vanishing angular radius from the bulb end of the chamber toward the middle. Beyond this, on the right, nuclei are too small to respond to the given pressure difference, δp, and the B side remains clear on exhaustion. As the time of exposure to the X-radiation is increased from 1 to 10 minutes, the nucleation of the A side becomes denser, coarser, and nonuniform in distribution, vertically as well as horizontally, while the efficient nuclei are found in continually increasing numbers, and at greater distances on the B side, until they eventually occur throughout the chamber. The growth of the coronas seen on the first exhaustion after successively increasing times of exposure show a characteristic sequence of types (figs. 2–6, Chapter I), as they pass (when seen through plate-glass apparatus) from roundish to oval, spindle-shaped, gourd-shaped with a long serpentine neck, and finally wedge-shaped forms, showing, therefore, continued symmetry about the middle horizontal plane or plane of vision, in spite of the whirling rains and densely stratified fogs which accompany the advanced condensations. The design lasts but an instant, for although the nuclei may be suspended in accordance with the given distribution, this is not possible for the heavy fog particles after condensation.

These phenomena bear fundamentally on the origin of persistent nuclei, and these are obviously graded in size, decreasing from the A to the B sides, as well as from the middle plane toward the top and bottom of the fog chamber. With regard to the latter or horizontal symmetry, moreover, the distortion is such that the fog particles must increase in size, from the plane of symmetry down and up.

If the gradation is linear, for instance, with a coefficient, a, so that $d=d_0-ah$, where d is the diameter of fog particle at a height or a depth, h, from the plane of sight, and s the radius vector from the coronal center to a locus of uniform color, α, the angle of s with the horizontal,

$$s=-(d_0/\sin\alpha)\left(1-\sqrt{1+2as_0\sin\alpha/d_0}\right).$$

These curves are campanulate in outline, passing from closed roundish to open basin-shaped forms, and two examples, a and a', are shown in figure 7, Chapter I. They all intersect at b and c, and the ends lying outside these lines may obviously here be ignored. As the march from a to a' is one of intensified gradation, the curves eventually becoming flat, it is clear that the horizontal symmetry of figures 2 to 6 is suggested. The latter contain, in addition, the essential gradation from left to right, due to the position of the bulb.

107. Origin of persistent X-ray nuclei.—Admitting that the fog particles are larger from the middle plane toward the top and bottom of the fog chamber, the nuclei must either be large in size toward the top and bottom as well as toward the bulb, or they must be smaller in number. The latter case may be dismissed. It follows, then, that the layers of stagnant, originally dust-free, air within the chamber become more and more rich in relatively large nuclei as they lie nearer the top and bottom and the end. (The corresponding effect toward and from the line of sight will, of course, remain invisible.) These large nuclei capture nearly all the moisture in the parts in question, giving rise to the whirling rains and dense fogs after condensation, whereby the essentially unstable character of this distribution is made manifest.

Hence the case is such as if the persistent nuclei were generated by the impact of the X-rays of sufficient intensity on solid and liquid parts of the vessel, recalling the way in which similar nuclei are produced by ignition and by high electrical potential, etc. Or one may state that the secondary X-radiation, which plays near the walls of the vessel, is particularly intense near those walls, so that the growth of nuclei in the field of ionized air adjoining is most rapid near those parts. In any case the number of efficient nuclei near the horizontal plane of symmetry is apparently large, because these nuclei are nearly of a size and all are therefore available for condensation. The number of efficient nuclei near the walls is smaller because large and small nuclei are here intermixed, and the former capture nearly all the moisture in those parts. The actual nucleation here must, however, be exceedingly large, and it is because of the relatively great density of the nucleation in question that rapid and pronounced growth of nuclei become possible.

Thus there must be many nuclei which fail of capture in the first exhaustion, and for this reason, finally, the coronas on second (otherwise identical) exhaustion, without fresh nucleation or exposure to the X-rays, are invariably phenomenally large and may correspond to one-third or one-half as many nuclei per cubic centimeter as the first coronas.

108. Order of size of persistent X-ray nuclei.—This may be expressed in terms of the pressure difference needed to produce condensation. Unfortunately the coronas on first exhaustion are apt to be distorted or dense fogs, while as the pressure difference, δp, decreases they become more and more diffuse and equally unsuitable for measurement. I have, therefore, computed the number of particles, N_2, present on second exhaustion for a given nucleation. These coronas are smaller, but sharp, and the fog particles are condensed on the water nuclei resulting from the first exhaustion. One may estimate roughly that about 10 per cent of the original number of nuclei are condensed in this way. The following is an example of results for 3-minute intervals of exposure to the X-rays (curves 38, 39, Chapter II):

$\delta p=$	33	25	17	9	4	17
$N_2\times 10^{-3}=$	15	46	47	28	14	46

The passage through a maximum at $\delta p=16$–20 is capable of a variety of explanations, and therefore of little interest. The important point at issue is the fact that these nuclei require almost no supersaturation for condensation. Filmy coronas are produced by vanishing pressure differences. It follows, then, that these nuclei are about of the size of ordinary dust-like nuclei.

109. Ordinary nuclei.—The persistent nuclei of section 108 were produced by radiation in a medium of damp air, with the specific object of avoiding the introduction of foreign matter into the fog chamber. It is well known, however, that nuclei are producible by any profound method of trituration which may be mechanical, as in the comminution of water by agitation or by the impact of jets. The resources used may be of a more refined physical character like ignition or high electrical potential, or of a chemical character like combustion and the slow oxidation of phosphorus, etc. It is noteworthy that in all these processes not only is ionization present, but that the ionization and the nucleation produced in any definite process are proportional quantities. This important result is demonstrable with phosphorus nuclei by using the condenser and electrometer as usual for the ionization, and the steam jet for the nucleation; or, with water nuclei, by comminuting water by the aid of jets in the fog chamber, determining the nucleation by the coronal method and the ionization by discharging the air laden with water nuclei through a tubular condenser. In both these cases a definite amount of nucleation or ionization is producible, and may be varied under control at pleasure.

The slopes of the lines in the relation between the coulombs per second passing radially in the tubular electrical condenser and the liters per second of air saturated with phosphorus nuclei passing longitudinally through the condenser into the steam tube, differ in different experiments, whereas the colors of the field of the steam tube referred to volumes of charged air per minute are in general agreement; *i. e.*, whereas the nucleation is a fixed quantity, the number of electrons per nucleus varies with the incidentals of the experiment. Inasmuch as the ionization is subject to relatively very rapid decay while the nucleation persists, a result of this kind is to be anticipated; but detailed investigations on the rates at which the ions and the nuclei are severally produced in any given process, and their relations, seem to me to be of great importance, and are now in progress at this laboratory.

110. Ordinary dust-free air an aggregate of nuclei.—The steam jet* shows that nuclei of small relative size, but, nevertheless, large as compared with the molecules of air, must normally be present in dust-free air; for the axial colors may be kept permanent at any stage by fixing the supersaturation. Such nuclei may be called colloidal molecules, even the largest being much smaller than the ions. Moreover, the available nuclei to be reckoned in millions per cubic centimeter increase with enormous rapidity with the supersaturation in

* *Cf.* Barus: Bulletin U. S. Weather Bureau, No. 12, 1893, Chapter III.

proportion as the molecular dimensions are approached. But even when the yellows of the first order vanish, condensation probably still takes place on the colloidal molecules specified. It is natural to associate these extremely fine nuclei with the existence of a very penetrating radiation, known to be present everywhere. Moreover, the occurrence of many nuclei with but few ions is not contradictory, if the latter are only manifest when the former are made or broken, in the manner suggested above (section 89).

111. The nucleation of filtered air.—If the filtration is moderately slow, and if the pressure difference, δp, continually increases, the angular coronal diameter or its equivalent, s, terminates in a horizontal asymptote, as shown, for instance, in Chapter III, figure 45 *et seq.* Hence the number of efficient nuclei in the exhausted receiver eventually approaches a constant, specific for the given rate of filtration. It is probable, therefore, that extremely small nuclei or colloidal molecules (very small even when compared with ions) pass through the filter; for in such a case more nuclei would enter the fog chamber during the influx of filtered air to replace that removed by exhaustion, in proportion as this exhaustion (δp) is higher. Hence s should be constant in the manner actually observed. The study of the successive groups of nuclei in a scale of decreasing smallness promises to be interesting.

If the current of air through the filter is successively decreased until its velocity all but vanishes, the asymptote in question may be raised enormously until the curve runs upward with a nearly straight sweep. Thus, for extremely slow influx of filtered air to restore the normal pressure after exhaustion, values like the following appear:

$\delta p=$	24	30	33	37	41
$s=$	rain	5.4	5.8	7.2	7.3
$N \times 10^{-3}=$	1	105	143	280	351

data which, from the nature of the work, are inevitably somewhat irregular, but which do not even suggest an asymptote, and from which the character of figure 46 has departed. These nuclei can not come through the filter, for which case $s=$const. would be conditional. The fact may also be proved by making observation but once in 24 or 48 hours, in which interval all nuclei originally present would vanish by time loss, unless constantly reestablished as a case of molecular equilibrium, as already suggested. It is possible to filter slowly enough that, *cæt. par.*, a specific nucleation may appear for each pressure difference.

Experiments have been in progress in this laboratory since May 9, in which the nucleation of filtered air is examined daily with regard to its time variation. To guard against errors of interpretation, it was necessary to install two fog chambers side by side, drawing from the same filter and utilizing the same exhaustion system. In spite of the fact that all appurtenances are apparently identical, the two chambers do not show even approximately the same coronas or the same nucleation. Each behaves as if it had its own specific coefficient of radio-activity. Furthermore, the coronas for the same high pressure difference ($\delta p=41.5$) vary in the lapse of time as if some external radiation were involved, though such a conclusion would not as yet be trustworthy. It was shown above that the efficiency of the very penetrating gamma rays in producing nuclei is very marked, but the nuclei here in question are very small in comparison with the cases examined.

112. Nucleation of atmospheric air, not filtered—Dust contents at Providence, R. I.—In the belief that a highly nucleated medium, no matter whence the nuclei may arise, is a medium of special interest, measurements of atmospheric nucleation have been in progress at this laboratory since 1902. Four or more observations were usually made by the coronal method per day, the details of which can not, however, here be instanced.* If the mean of the daily observations be taken, they make up a number of cotemporaneous series, the properties of which are best shown graphically. Apart from details, for which there is no place here, the things noticeable in the curves of successive years are the extremely high winter, as compared with the summer nucleations, the efficiency of rain in depressing the nucleations, and the totally different character of the curves for 1902–3 and 1903–4.

These may be made even clearer by comparing the average monthly nucleations, as are shown by the graphs in figure 103 of Chapter V, in which the ordinates are again the nucleations in thousands per cubic centimeter. (*Cf.* figs. 102, 104.) Here the degree of difference and the similarities of the two curves are strongly brought out. As to the latter, both tend to show sharp maxima near the time of the winter solstice, and flat minima, much subject to rain, at about the time of the summer solstice. It is clear from the enormous difference of nucleation at the maximum and at the minimum that astronomical causes can not be directly involved. The origin of the nucleation must be in large part local, the nuclei themselves being the initially ionized products of combustion. Nucleation is depressed by rain, and possibly also (from the length of the summer day as compared with the winter day) by light pressure.

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* *Cf.* Smithsonian Contributions, Vol, XXXIV, 1905.

113. Continued—Dust contents of atmosphere at Providence and at Block Island, R. I., compared.—To interpret the curves in question fully, *i. e.*, to ascertain whether there may not, after all, be a cosmical effect, superimposed on the local effect observed, it is necessary to make a series of observations at a station more remote from the habitations of man. Measurements were therefore made at Block Island, under my direction, by Mr. R. Pierce, jr., simultaneously with my own observations at Providence, by the identical coronal method in question. The stations are sufficiently close together to have nearly the same meteorological elements as to wind and weather, but Block Island lies well out at sea, and is, in the winter at least, nearly free from local effect.

The average daily nucleations for both stations are shown in figure 102, Chapter V, and, as was to be anticipated, those at Providence are much in excess. Leaving these for discussion elsewhere, sufficient may be learned from the average monthly nucleations in the two places, given in figure 104, Chapter V.

In both cases there was an evident tendency in 1904–5 to reproduce the curves of 1902–3 and 1903–4, with the sharp maxima in December, and thereafter a rapid march toward the flat summer minimum. In both cases, however, there is a new effect in February, which, by being superimposed on the local nucleations at Providence, does not appear further than as a determined departure from the curves of the preceding years, but which juts out into striking prominence in the observations at Block Island, where the local effect is relatively negligible. Apart from quantity, the fluctuations of both curves are identical in character.

Finally, as to causes of the usual solstitial maximum and minimum, and of the accessory maximum in February of this year, they may represent the diluted local effects averaged by the sweep of the winds for an enormous extent of territory. But it is quite as reasonable to keep one's mind open to the possibility that the February maximum, at least, may represent an external invasion of the atmosphere on the part of some external nuclei-producing agency.

TRADITIONS OF THE CADDO

COLLECTED UNDER THE AUSPICES OF THE
CARNEGIE INSTITUTION OF WASHINGTON

BY

GEORGE A. DORSEY
CURATOR OF ANTHROPOLOGY, FIELD COLUMBIAN MUSEUM

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CONTENTS.

INTRODUCTION.

THE Caddo tales here presented were collected during the years 1903–1905, under the auspices of the Carnegie Institution of Washington, and form part of a systematic investigation of the religious system and ceremonial organization of the tribes of the Caddoan stock.

The Caddo, numbering 530 in 1903, are of Caddoan stock, and since 1859 have lived in western Oklahoma between the Washita and Canadian rivers, where they have been closely associated with the Wichita. They retain practically nothing of their ancient culture. Their early home was in Louisiana, on the lower Red River. Later they migrated toward the Texas border, and still later to Brazos River in Texas. They met the whites as early as 1540, and throughout their history have maintained a friendly attitude toward the whites. Like the Wichita, their early habitations were conical grass lodges, and they were agriculturists, hunting the buffalo only within comparatively recent times.

The comparison of the Caddo tales with those of other tribes is deferred until the completion of the present investigation.

GEORGE A. DORSEY.

Chicago, July 31, 1905.

TRADITIONS OF THE CADDO.

1. THE CREATION AND EARLY MIGRATIONS.*

In the beginning the sun, stars, moon, and earth did not exist as they are now. Darkness ruled. With the lapse of time came a man, the only living being. Soon after his arrival a village sprang into existence with many thousands of people, and the people noticed that the man seemed to be everywhere. For a time he disappeared, and when he came back he had all kinds of seeds. He called all the people together and told them that the seeds were for them to eat, and gave them to every one. He told them that soon Darkness would go, and the people would see, for Darkness had promised that they should have a man by the name of Sun, and that he should be given power by the Great-Father-Above; that whenever his time should come to give them to the Sun he should be called or taken away from his mother, from our great mother Earth below; that the direction where the Sun should come from should be called "east," and the way of its going down should be called "west." He also announced to the people that he was the first being created and that he had been given power by the same Great-Father-Above, and that he had to carry out his work. He then told the people that it was very necessary that they should have one man abler and wiser than any other man among them, to be their head man; that they should call him "chief;" that whatever the chief should command should be done by the people; that they should look upon him as a great father. The unknown man told the people to return to their homes, hold a council among themselves, and select a chief.

When they had returned and assembled there was in the council a man by the name of Coyote, who told the people that the unknown powerful man should be called Moon, because he was the first man created on earth. The people decided that the Moon should be their head man or chief. Finally the Moon called the people together again and asked them if they had selected their head man or chief. Coyote told him that they had decided that he should be their head man, and that they had named him "Moon." After Moon came to be chief he selected another man, whom he called the Errand-Man, to be his helper,

* Told by White-Bread.

and to go around among the people to call them together whenever he might want them.

One time the errand-man was sent out to tell the people that the chief wanted them to assemble; that he had very important news to tell them, and that they should come as quickly as they could. When they had come together the chief told them that they would all have to move away from the world that they were living in to another and better world; that he was going to lead them through, for he knew the way. The village which they were going to leave was called Old-Home-in-the-Darkness. Before the people were ready to leave, the chief sent the errand-man around among them to tell them that they were to be divided into groups, because there were so many of them; that each group must have a leader, and he would give each leader a drum. The people began to form in groups and select their leaders. After the groups were all formed and each selected their leader, the chief called all the leaders together and gave each a drum, and then they were ready to start. The chief told all the leaders that they must sing and beat their drums as they were moving along; that none of them should ever look back the way they came, lest the people should be stopped and have to stay where they were—in darkness.

The people began moving westward, and they came out of the ground to another world. While they were yet coming out Coyote happened to be out. He began to look around, then told the chief that the world was too small for the people; then he turned around and looked back in the direction from which they had come. The people had not all come out, and so half of them went back, but the others kept on going westward. Finally the chief picked up some dirt and threw it in front of him and formed very high mountains. When the people came to the mountains they stopped and began to make their first homes and villages. Moon went to the top of the mountain and looked about and found that the people had not all come the way he had come, but had scattered and gone in different directions. At the time when the people were all together they spoke but one language, the Caddo; but after they had scattered out in groups each group spoke a different language. For this reason the many tribes of the present time speak different languages. When Moon came to his people, the few he had left, he told them the name of the place in the ground from which they had come. He told them that the direction to their right-hand side should be called north, or cold side, and the direction to their left-hand side should be called south, or warm side. While Moon was talking the Sun came up out of the east, passed them, and went down in the west. He went too fast to do them any good at all. Coyote announced that he was going to stop the Sun from going so fast. He started eastward early in the morning, and when he came to a good place to stop he waited for the Sun to come up. When the Sun came up he found Coyote waiting for him. Coyote told the Sun that he had come there for the purpose of seeing him; that he wanted to talk with him, for he was in trouble. The Sun said that he had not very much time to stop and talk. Coyote told the Sun that he would go with him and talk to him as they went along. They started on, walking very slowly. Coyote kept telling about things that had lately happened. When the Sun was nearing the west Coyote told him that he was going to defecate, and asked him to wait a while. He started out behind the bushes, and just as soon as he was behind them, where the Sun could not see him, he ran away from the Sun and the Sun stood there waiting for him to return. After a while the Sun grew tired of waiting and started on very slowly, looking back every little while and watching for Coyote to catch up with him, but Coyote did not appear. The Sun went down very slowly, still waiting for Coyote. This is the reason that the Sun lingers and goes down very slowly.

The people's first village in this new world was called Tall-Timber-on-Top-of-the-Hill, for the place was in black-jack timber near the top of a high hill. There was the beginning of the real people. Moon called the people together for the first time in the new world and said: "Soon there will be a child born of a certain woman. He is on the way. He shall have more power than any one else, for Great-Father-Above has sent him down to his mother, the earth, to be among the people and teach them right and wrong. When the child comes he shall name himself after the former chief, Medicine-Screech-Owl, and he shall have with him bow and arrows."

When the child came he had with him the bow and arrows. When his birthday came his father and mother were talking about what name should be given him; but before his mother or father could give him a name the young child spoke and named himself, saying, "My name shall be Medicine-Screech-Owl." He said to the people: "The bow and arrows are for the men only, to be used in killing game. The time is coming when we shall have to use these things, especially the bow and arrows." Later on the people began to learn that this child was going to be a powerful man. He went around among the people and taught them how to make bows and arrows. In those times the animals talked to human beings and the human beings could talk to the animals, and they understood one another. Time passed and some of the human beings began to turn into animals. Medicine-Screech-Owl knew that some of these people were not real human beings. He knew that if some of the people should turn into animals it would be very bad, as the people would be destroyed by them, and as he knew just what animals were the most ferocious he went and made them a visit in behalf of the people. Some of the animals were opposed to Medicine-Screech-Owl and hated him, and when he came to certain ones they would try to kill him, and that is how he came to kill some of them.

In those times the people had little to eat. There were two people, a man and a woman, known to the people as the Buzzards, who lived at the north end of the village, and the people noticed that they always had plenty of meat and other things to eat, and they wondered how they got it. Time passed until finally Coyote came among the people and told them that he was going over to visit the two people and find out where and how they got so much meat and so many other things to eat. In those times the animals that were living with the people had some magic powers, and Coyote had power. He said: "In order to find out where and how the Buzzard people get their food, I must scheme." After studying he resolved that he would imitate a dog, and so before he came to the Buzzard home he turned himself into a very small and fine-looking dog. He stayed away from the Buzzards and watched his opportunity to place himself where they would find him. One time the Buzzards had gone out some distance from their home for some purpose and were returning, when they found the little dog by the trail. The woman liked the dog, but the man said that it was not a real dog, but some one else. The woman did not believe him. The man allowed her to take the dog home with them. When they reached home he told her that they must find out whether this was a real dog or not. He told her to pinch the dog's ear and see if it would howl like a real dog. The woman pinched the dog's ear and it howled like a dog. Still the man did not believe that it was a dog. He told the woman to go and get some meat and give it to the dog, saying that if a dog it would take its time, but if it were not a dog it would eat fast; that then he would know whether or not to believe it was a dog. The woman gave some meat to the dog. Coyote took his time in eating it, and so Buzzard believed what the woman had said, and they kept the dog. Coyote stayed with them until their meat gave out, then he watched them very closely. Finally the Buzzards began to talk about going after more meat. Coyote listened. At length they started out and left their dog at home. They thought the dog would stay at home until they returned. But Coyote had a scheme, so he followed at some distance, so that they could not see him, and he watched them very closely. When they came to the place where they usually found their meat, Coyote found out all about how and where they got it, then ran back to their home and lay down, so that when the Buzzards returned to their home they found their little dog lying there fast asleep. Coyote stayed with them two days longer, and the third day he made up his mind that he must carry out his work. Early one morning he started out straight to the place where he had seen the Buzzards at work. It was a large cave or hole in the ground. The door of the place was a large rock. When he came to the place he opened it and out came thousands and thousands of buffalo. They came out so fast that before long they had spread over the western prairies before the Buzzards knew it. It was quite a time before Buzzard discovered what had happened. First he heard a strange noise like thunder. He went and looked for the little dog, but in vain, for the dog had already gone. He heard Coyote howling in the distance. Buzzard went out and found that nearly all the buffalo had escaped.

When Coyote went to his home he told the people to hurry and make some bows and arrows, for the buffalo were coming. He told them just what had happened and how he had schemed.

Buzzard was very angry at his wife and scolded her. He told her that she ought to know by this time that they were not the only ones that had powers, and that henceforth the only way that they could make a living was to go around and look for dead meat. In order to do this they turned into birds and became real buzzards. They flew around and looked for dead things to eat.

From that time on the people began to make bows and arrows, which were given to mankind for their use in killing game. Time passed on and the people noticed that their chief, Moon, paid no attention to them and seemed to have nothing to say. He did not call them together any more, but stayed at his home all the time. The people began to think there must be something wrong, and so there was, for Moon himself was doing very wrong things. He knew that he was setting his people a bad example, and he believed the people had already found out something about him. Medicine-Screech-Owl knew all about this, for he had more powers than Moon himself. Moon was living with his family near the center of the village; he was the chief, unmarried, and lived with his father and mother and one very young sister. Here was the beginning of his mistakes. Unknown to his father and mother, for a long time he kept going by night to see his own sister, not letting her know that he was her own brother. He abused her and treated her very meanly sometimes. For a long time she did not know who he could be, for she had no one to tell her. It finally occurred to her that it might be her brother. One night she made up her mind to find out who he was. She put some black paint on her fingers, and that night when the man came she passed her painted fingers across his forehead and made black marks, which the man knew nothing about until the next morning. In the morning, when he came in, she saw the marks on his forehead, and she knew that he was the man who had abused her. When he learned that the people were finding out about him he became so ashamed of himself that he wished to leave his people. He remembered that when he came into the world the Great-Father-Above had promised him that some day he should call him away from his people; that he should be placed where the people could see him at night, and that he should be with the people all the time. He knew that the time was now approaching when he should be called away from his people, and soon he was called away from them. Great-Father-Above took him away and placed him far above, where the people could see him and the shame-marks on his forehead.

Medicine-Screech-Owl grew to be a man, and after Moon was gone the people gathered again to select another chief, and they selected the powerful Medicine-Screech-Owl. His first announcement to the people was that they must move on farther west. The people began moving westward, climbing the mountains. When they had got on top of them they saw a large lake, and they wondered where the water came from. Medicine-Screech-Owl called the people's attention to it, and they all came and gathered along the banks of the lake. He then spoke to the people, saying: "These waters which are before you are the tears of your great chief, Moon, for before he was taken up into the heavens he came up to this mountain and shed tears for the wrongs he had done to his people. So we shall call this mountain Moon's-Tears-on-the-Mountain." The people kept on moving westward until they found a place where they wanted to locate their second village. They commenced making bows and arrows, which they used in killing game. They began to go out a long distance from their village to hunt buffalo and other animals. There were several kinds of dangerous animals in the country, and at one place near by the people dared not go, because there in the water was the most ferocious animal that ever lived. Medicine-Screech-Owl told the people that he had some power and that he was going to try to kill the animal. One day when he was alone he decided to go and destroy the animal. He went out, and when he came near the place where the animal was he stopped for a short time at the edge of the timber, for he could not locate the animal exactly. The name of the animal was Cannibal. The lake was large and all around were swamps and thickets. By the aid of his power and with a certain motion, Medicine-Screech-Owl made a narrow place like a road through the thicket, through which he could see the animal. He had brought with him from his village his bow, but no arrows, and some corn, which he was to use in killing the animal. When he made the opening in the thicket he took out two tall canes from the ground, with the roots and the dirt that was on them, to be used as arrows. The corn that he had with him he threw in the air, and it became blackbirds, which flew straight over the head of the animal. When the animal arose to draw the blackbirds down to him Medicine-Screech-Owl shot it with the cane arrows, first from the right side through the heart and out the left, then from the left side through the heart and out to the right. The animal fell near the edge of the water and died. Medicine-Screech-Owl went over to see the place where the animal was. He saw all kinds of bones lying around the place. Not long after this the lake dried up. When the people learned what had happened and what their chief had done, they were no longer afraid of the place.

Now Coyote became a very bad man. The people noticed that he had done to them several things that he had no right to do. He would go from place to place, sometimes very early in the morning and sometimes very late in the evening. He made all kinds of trouble among the people. Whenever he did anything that was wrong he would blame some one else, and in some way he would escape the consequences. Finally Medicine-Screech-Owl sent for Coyote and told him that he must leave the people and go on his way; but Coyote, being a great schemer, told the chief that he was going to stop doing mean tricks among his people, and that he was not yet ready to leave. Medicine-Screech-Owl allowed him to stay with the people until he should be captured or killed at any time.

2. THE ORIGIN OF DAY AND NIGHT.*

In the beginning the people all lived in darkness. After a time they became dissatisfied and wanted light. They called a council to discuss how they could get light. Coyote was the first to speak, and he said: "We have had enough darkness; we must now have light. It is right that we should have both and not all darkness." There was a man at that time who was a prophet, and Coyote said that he appointed the prophet to investigate and see how the people might obtain light. The prophet thought over the question and then reported:

"There are yellow, black, spotted, half-spotted, and white deer upon the earth. These deer are here for some purpose. If you kill the yellow

* Told by Wing.

deer, everything shall be yellow all the time. If you kill the white deer, everything shall be white all the time. If you kill the spotted one, everything shall be spotted and very bad. If you kill the black one, everything shall be black as it is now. But if you kill both the black and the white deer, then we shall have day and night. During the day everything will be white, and we can go about and hunt and visit, and during the night we can return to our homes and rest."

The people accepted the prophet's words and started out and hunted until they killed the black and white deer, and from that time we have had day and night.

3. THE ORIGIN OF ANIMALS.

The people and animals all lived together and were the same in the beginning of the world. After a time they became too numerous and there was not food enough for all. A council was held and the chiefs determined that some should become animals and live apart from the people and be hunted by them for food. Some of the people, who lived where the big fire had burned off the grass, were rolled about in the black ashes until they became black. Again they were rolled and then they took on the form of bears. Long pieces of white stone were put upon their feet for claws and in their mouth for teeth. They were given ten lives. When killed the first time, the second life was to arise from the blood that was spilled upon the ground, and so the third life was to arise from the blood that was spilled when the bear was killed for the second time, and so on through the other lives up to the tenth. During the first life the bear was not to be fierce, but as often as he was killed and passed to another life he was to become fiercer and fiercer, until, when he came to the tenth life, he would fight, and even eat, human beings.

Some other people who lived where the long grass grew were rolled upon the earth, and when they arose they had the form of buffalo, and the grass had stuck to them and hung all like a beard under their necks. They, too, were given ten lives and then put upon the prairie to live, where man could hunt them. The deer were then made in the same way, and after them all the other animals were made.

4. COYOTE REGULATES LIFE AFTER DEATH.*

The people had many councils from time to time. The errand man went all round to call the people to these councils. At one council Coyote arose and said: "First, we must change our rule about death, because all are not being treated alike. Now when some die they come

* Told by White-Bread.

back to their people, and then others die and never see their people again. I propose to make another rule, so that we may all be treated alike after death. This is the rule that I wish to propose: When any one dies let him be dead forever, and let no living person ever see him again. Our Great-Father-Above made a place there where every one of us may go after death. Now when any one dies he shall go from the living forever, but we shall still keep up the fire for six days." All the people were well pleased with Coyote's rule, and so from that time on, even to the present day, the same rule is kept, and when anybody dies he is gone forever, never to return again. The people are taken to the sky when they die and become the stars that we see at night.

Morning Star, who freed the earth from bad animals, had three brothers, and he was the oldest one and the leader of all the tribe. In the beginning he had been the errand man, and during war expeditions he had to get up early in the morning, hours before dawn, to go around the camps and wake the people, so that the enemy would not find them. That is the reason he gets up so early now. In the evening one of his brothers would go back a long distance to see if the enemy were coming on their trail, and so the man was named Evening Star. The other two brothers were named North Star and South Star, and these four brothers always had something to do. North Star always had to camp in the North and watch for the enemy lest they should approach from that direction; South Star had to camp in the South and watch lest the enemy should approach from that direction. Their father's name was Great Star, and he was the chief of the people. Now the people think that when any one dies he goes up to the sky, where he turns around and looks back and becomes one of the stars, and so they believe every one when he dies goes up to the sky.

5. COYOTE AND THE ORIGIN OF DEATH.

In the beginning of this world there was no such thing as death. Every one continued to live until there were so many people that there was not room for any more on the earth. The chiefs held a council to determine what to do. One man arose and said that he thought it would be a good plan to have the people die and be gone for a little while, and then to return. As soon as he sat down Coyote jumped up and said that he thought that people ought to die forever, for this little world was not large enough to hold all of the people, and if the people who died came back to life there would not be food enough for all. All of the other men objected, saying that they did not want their friends and relatives to die and be gone forever, for then people would grieve and worry and there would not be any happiness in the world.

All except Coyote decided to have the people die and be gone for a little while, and then to come back to life.

The medicine-men built a large grass house facing the east, and when they had completed it they called all of the men of the tribe together and told them that they had decided to have the people who died come to the medicine-house and there be restored to life. The chief medicine-man said that he would put a large white and black eagle feather on top of the grass house, and that when the feather became bloody and fell over, the people would know that some one had died. Then all of the medicine-men were to come to the grass house and sing. They would sing a song that would call the spirit of the dead to the grass house, and when the spirit came they would cause it to assume the form that it had while living, and then they would restore it to life again. All of the people were glad when the medicine-men announced these rules about death, for they were anxious for the dead to be restored to life and come again to live with them.

After a time they saw the eagle feather turn bloody and fall, and so they knew that some one had died. The medicine-men assembled in the grass house and sang, as they had promised that they would, for the spirit of the dead to come to them. In about ten days a whirlwind blew from the west, circled about the grass house, and finally entered through the entrance in the east. From the whirlwind appeared a handsome young man who had been murdered by another tribe. All of the people saw him and rejoiced except Coyote, who was displeased because his rules about dead were not carried out. In a short time the feather became bloody and fell again. Coyote saw it and at once went to the grass house. He took his seat near the door, and there sat with the singers for many days, and when at last he heard the whirlwind coming he slipped near the door, and as the whirlwind circled about the house and was about to enter, he closed the door. The spirit in the whirlwind, finding the door closed, whirled on by. Death forever was then introduced, and people from that time on grieved about the dead and were unhappy. Now whenever any one meets a whirlwind or hears the wind whistle he says: "There is some one wandering about." Ever since Coyote closed the door the spirits of the dead have wandered over the earth, trying to find some place to go, until at last they find the road to spirit land.

Coyote jumped up and ran away and never came back, for when he saw what he had done he was afraid. Ever after that he ran from one place to another, always looking back over first one shoulder and then over the other, to see if any one was pursuing him, and ever since then he has been starving, for no one will give him anything to eat.

6. THE SECOND MAN WHO CAME OUT OF THE EARTH.*

In the beginning, when the people first came out of the earth into the world, Moon was the first man to enter the world. The second man was Tonin, and he was even greater than Moon and more powerful. He was only about four feet high and rode a bay horse that was no bigger than a dog. He had the power to turn darkness into light, and to wish for anything and have his wish fulfilled at once. If he wished to go a long distance, no sooner did he wish than he was there, no matter how far, and if he wished to kill any kind of game, all he had to do was to point to it with his forefinger and it lay dead before him. From time to time he disappeared and the people did not know where he went, until one time they saw him going as though on wings up into the blue sky. He was able to tell what would happen in the future, and so one time he sent the errand man to go out and call all the people to come to the meeting place, for he had something that he wanted to say to them. When the people were all assembled, he came and talked to them for half a day. He talked to them about this world in which they were living, and then he told them that in six days he was going away, and that he would be gone six winters and seven summers. He told them that he did not know exactly where he would go, but that he wanted them all to come in six days and see him start on his journey. The people went home and on the sixth day came again, and after they were there a little while Tonin came. He began to sing a song, the song of death, and then he was gradually lifted from the earth and taken into the sky. All the people wept for fear he would not come back, but they remembered his promise to return, and so took courage.

Time passed and the people remembered Tonin and his words for about three summers and three winters; then they began to forget about him and his words. Time passed on and it was time for him to return; then the world began to change. The stars became brighter and larger. Tonin had several brothers, and one of these brothers had remembered what he promised the people, so he knew that it was time for him to return. When the day came this brother gave the sign to his people that Tonin was about to return by beating six times on the drum; but some of the people had so completely forgotten Tonin that they did not even know what the sign meant. Toward evening a large star came up and shone very bright in the east, and all the people came and gathered together to watch it. When Tonin came back to earth he was pleased to see the people all there to meet him, and he

* Told by White-Bread.

told them about the future. He told them that strange people were coming into the land, and that they would frighten away the buffalo, the deer, and the bear. He stayed on earth some time, then called the people together and told them that he was going as he had gone before, but that this time he was not to return. Then he went up into the sky.

7. SNAKE-WOMAN DISTRIBUTES SEEDS.

The Great Father gave the seeds of all growing things to Snake-Woman. He taught her how to plant the seeds and how to care for the green things that grew from them until they were ripe, and then how to prepare them for food. One time, when Snake-Woman had more seeds than she could possibly care for, she decided to give some to the people. She called her two sons and asked them to help her carry the seeds. Each put a big bag full of seeds on his back, and then they traveled all over the world, giving six seeds of each kind of plant to every person. As Snake-Woman gave each person the seeds she told him that he must plant them, and must care for the plants that grew from them, but must allow no one, especially children, to touch them or even point to them as they grew. She said that until the seeds were ripe they belonged to her, and if any one gathered them too soon she would send a poisonous snake to bite him. Parents always tell their children what Snake-Woman said, and so they are afraid to touch or go near any growing plants for fear a snake will come and bite them.

8. THE FLOOD.*

One time a long, hot, dry season came and all the waters of the earth dried up. The people wandered from place to place, trying to find water, and after many days they became crazed and did many foolish things. They went to the dried-up river beds and there found many dead fish and turtles and animals that dwelt in the water, and the people cut them to pieces and threw them about, for they thought that these animals and fish were in some way responsible for the waters disappearing. While they were acting foolishly they looked up and saw a man in the sky coming toward them from the west. A wind blew, and the man approached and lighted on the ground before them. In his hand he carried a small green leaf. He told the people that they had not acted wisely and had abused him, and that he was angry with them. He motioned the leaf in four directions and drops of water fell from it. Soon the waters grew in volume and arose all over the world, even to the tree-tops, and the highest mountains except one. To this

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* Told by Wing.

high mountain the man led a few of the people whom he chose, and they stayed on the mountain for four days, while the water rose higher and higher. As the waters rose the man caused the mountain to rise with them. He could do this because he had greater power than the spirit of Cold or Heat. After a time the waters began to go down, and green things appeared upon the earth again. Then he led the people down from the mountain. They found that many people who had been left in the water during the flood had not drowned, but had turned into alligators and other water animals.

9. THE EFFEMINATE MAN WHO INTRODUCED STRIFE.

One time there lived among the people a man who always did the women's work and dressed like the women and went with them, and never went with the men. The men made fun of him, but he did not care, and continued to work and play only with the women. A war broke out with some other tribe, and all of the men went to fight but this man, who stayed behind with the women. After the war party had gone, an old man, who was too old to go with them, came to him and told him that if he would not go to fight he was going to kill him, for it was a disgrace to have such a man in the tribe. The man refused to go, saying that the Great Father did not send him to earth to fight and did not want him to. The old man paid no attention to his excuse, and told him if he did not go to fight he would have the warriors kill him when they returned from battle with the enemy. The man said that they could not kill him, that he would always come to life, and would bewitch people and cause them to fight and kill one another. The old man did not believe him, and when the war party came home he told the men that they would have to kill the man because he was a coward, and they could not let a coward live in the tribe. They beat him until they thought he was dead, and were just ready to bury him when he jumped up alive. Again they beat him until he fell; then they cut off his head. He jumped up headless and ran about, frightening all of the people. They were just about to give up killing him when some one noticed a small purple spot on the little finger of his left hand. They cut that out; then he lay down and died. Soon after many people began to fight and quarrel, and some even killed their own brothers and sisters and fathers and mothers. The other people tried to stop the fighting, but could not, because the people were bewitched and could not help themselves. Then the old man remembered what the coward had said, and he told the people, and they were all sorry that they had killed him.

10. THE ORIGIN OF THE MEDICINE-MEN.*

In days of old people knew the animals and were on friendly terms with them. All of the animals possessed wonderful powers and they sometimes appeared to people in dreams or visions and gave them their power. Often when men were out hunting and were left alone in the forest or on the plains at night, the animals came to them and spoke to them in dreams and revealed their secrets to them. The man who had had a dream of this kind woke up and went home. There he remained several days in silence, refusing to talk to any one, thinking only of the things that had been revealed to him. After a time he called some of his friends and the old men of the tribe to his lodge and told them of his powers and asked them if they would be taught his secrets. If they agreed the man taught them his songs and dances. After he had taught them all the necessary things they declared themselves ready to give a Medicine-Men's dance, and gave themselves the title of medicine-men. Then if any one was sick in the village and sought the aid of the medicine-men they prepared to hold the dance in behalf of that person, that they might try their powers of healing on him. They built a large grass lodge, and the dance was held in this lodge for six days and nights.

The first medicine-men ever to receive power and give the dance were two young brothers. These boys were brave hunters, and one time when they were out on the hunt night overtook them far from any habitation. They made a camp in the lonely woods and laid down to sleep, for they were very weary. In their sleep they both had a dream and in their dreams each met the other, and they dreamed that they were walking together toward the east. On their way they saw a man coming toward them, and he was walking rapidly toward the west. They met him and he stopped and talked with them in their language. After they had talked long, the man revealed a bag that he carried and said, "Choose from this any kind of medicine that you want. If you wish to live long and be hard to kill, take this," and he handed them certain medicine. When the boys had accepted it he said, "Now that you have the same power that I have, I will show you how to use it." He spent a long time teaching them how to use the medicine and then he continued his journey toward the west. At break of day both boys woke up, and each remembered his dream, but said nothing to the other or to any one, but thought long on what the man had taught him. After many months each began to try his powers.

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* Told by Wing.

After two winters war broke out with the Chickasaw people, and many were killed and yet many more were taken prisoners. The victorious Chickasaws marched home with their prisoners and booty, and every night when they made camp they held war dances and danced about their prisoners, who, bound, were placed in the center of the large ring of dancers. One night, after the dancing was over and the prisoners lay exhausted and cold, one of them, a young man, escaped. It was nearly morning and he had not gone far when the sun came up, and he heard the Chickasaws coming after him. He did not know what to do and was about to give up when he saw a hollow log. He crawled into it and the Chickasaws came to the log and went on by. He stayed in the log all day, and in the evening, after he had heard the Chickasaws return, he crawled out and went on toward his home. After two days he reached his village and there told his story. There were many men in the village who had been away when the Chickasaws made their attack, and among them were the two brothers who had received power in their dreams. By that time the Chickasaws were about five days on their way, but the men started to pursue them. The elder brother, whose name was Strong-Wind, was chosen to take the lead. After several days' marching they overtook the enemy. They came upon their camp at night, and they could hear the beat of the drums and the songs of victory before they found the camp. The night was very dark, and so the men had to wait until dawn before they could attack the camp. At the first light they rushed into the camp and killed many Chickasaws and rescued their prisoners. Strong-Wind and his brother were equal to ten men apiece, and so wonderful were their powers that they alone rushed into the midst of the enemy and killed many and took many women as prisoners. The Chickasaws were powerless before them, and even their own people stopped fighting to stare in wonder at the brave deeds of the two young men. The few Chickasaws who were left fled in terror and the party returned home rejoicing.

After many years, during which time the brothers practiced their powers in times of war, they died and the tribe was left without any medicine-men. Finally there was a very young man, who became a medicine-man through powers given him by the Black-Mountain-Bear. One time while he was out hunting he wandered far in quest of game, and before he realized it the sun was down and it was growing dark. He thought of his home and knew that he could not reach it before night. He made a shelter, lay down to sleep, and dreamed that he was walking on a narrow trail leading eastward. He looked ahead and saw a man sitting by the wayside with his head down. As he approached, the man raised his head, looked at him, and said: "My boy, I want to give you some medicine, for I want you to have powers like mine." The old man took out many roots and told the boy to choose six of them. He took six of the roots; then the old man told him that he would have to go before six men, each of whom would explain the power of one medicine and how to use it. The boy did not want to go to so many men for fear he would not have time, and so he gave back four of the roots. Then he thanked the old man and started on his way. Soon he saw another old man sitting by the trail, and as he approached, the man arose, and when he came up to him he began to talk to the boy and explained the use of his medicine. While he was yet on the way, going toward the third man, he awoke. He returned to his mother's lodge, but kept silent, and spoke to no one for many days, thinking always about his dream and the things that had been taught him. He wandered about alone, looking always for the medicine roots he had seen in his dream. After many months he found the plant.

Soon after there was a man in another village who was about to die, and when the young man heard of the sick man he determined to go and see him and try his powers. He called the medicine-men together and taught them the medicine dance-song that had been taught him in the dream; then they all went to the lodge where the sick man was. All the people wondered why the young man should call the men to sing medicine dance-songs for him, for they never thought of him as having power. He was with the sick man a long time before he could find out what was the matter with him. First, the dancers danced very slowly, and gradually increased the movement, as was their custom. So long was the young man in finding out what was the matter with the sick man, that the dancers were dancing as fast as they possibly could before he decided. Thus they danced for six days and nights, and many of the dancers dropped to the ground exhausted. Finally the young man began to talk in a tongue no one understood, and he began to dance slowly. Then the others knew that he had discovered what ailed the man. He fell to the ground and began to crawl like a mad bear. He crawled up to the sick man and, placing his mouth on the place where the greatest pain was, drew the pain out by blowing his breath on the place, and the pain was gone. The people knew then that the boy was in truth a medicine-man, and by his actions they knew that the Black-Mountain-Bear had given him power. It was the Bear who had appeared to the young man as an old man in his dream. From that time he was called Black-Mountain-Bear-Medicine-Man. Then the chief of the medicine-men's society announced that all the medicine-men were going to hold a dance, and they wanted the young man to be present and show his powers, if he had any. The dance was held and every one attended. Black-Mountain-Bear-Medicine-Man sat and watched the dancers until the last, the sixth night of the dance; then he arose and joined in the dance. He danced faster and faster, and after a time went over and picked up a gun. He took the bullet out, then he showed it and the powder to all the people. Then he put them in the gun again and gave it to his helper. He continued dancing, and after he had danced a long time and very fast he fell to the ground. After a while he arose on his knees and spread out his arms. His helper shot him through the breast and he fell over in a faint. Soon he arose and began dancing again, and as he danced he showed the bullet to the people and also bared his breast, and they could see no marks. He had caught the bullet in his hands. After that he became a member of the medicine-men's society.

After a time another young man appeared with wonderful power, also given him by the Mountain-Bear. He appeared at the medicine-men's lodge one night, where they were having a dance, and he joined in and did many wonderful things. He had a bear's skin that he could cause to turn into a young bear, which would follow him about, and then he would turn the animal back into a piece of skin.

There are two kinds of medicine-men. One kind has power to doctor and heal the sick; another has the power to prevent any one from being hurt or harmed, and can charm away all danger. The latter are supposed to be more powerful than the first kind of medicine-men, for they can perform their magic without medicine and have power to bewitch people who are afar off, and thus make them lose their minds and not know what they are doing. They have a song of death, and when they sing the song before a dying person they frighten away death and the person lives. There are few people who ever receive this power, which is generally given by the sun, moon, stars, earth, or storm, but some very wild and ferocious animals can also give the power to people.

11. THE GIRL WHO MARRIED A TURTLE.

A girl lived alone with her two brothers. They were famous hunters and were away all day hunting. While they were gone the girl often played down by the water, and there she came to know Turtle. One day he came up to her and asked her if she would have him for her husband. She said that she would, and after that she met him whenever she went to the lake. Often her brothers wanted to carry the water for her, but she would never let them, but would always go herself and stay a long time with Turtle. One time her brothers went away to be gone many days. She told Turtle that they were gone and that she was going to take him to her house and keep him there. He was glad, for then he could be with her all of the time. She went home and built a high bed, and when she had finished it she carried Turtle home and put him in the bed. She asked him what he liked best to eat, and he said that he liked potatoes better than anything else. Every day she went out to hunt potatoes and prepared a big bowl full and put it up in the bed for him to eat. After several days her brothers came home, and so she thought she would take Turtle back to the river, but he begged so hard to stay that she yielded to him, though she knew that she took a risk. She told Turtle that he must always stay up in the bed where her brothers could not see him and must not move when they were about, for they would hear him and look for him and would surely kill him if they found him. The boys noticed the high bed when they returned, but their sister told them that she had made it because she felt safer in it while they were gone. Then they thought nothing more about it until they noticed that their sister regularly filled a large bowl with potatoes and put it in the bed and then took it out empty. They began to suspect something, but said nothing. One day they said that they were going to hunt. The girl watched them until they were out of sight; then she took her digging stick and started after more potatoes for Turtle. The boys only pretended to go hunting and soon came back. They slipped up to the house and peeped in. When they found that their sister was gone they went in and climbed up to the bed to see what was there. They found Turtle and killed him, then ran away. When the girl came home and found her husband dead, she knew at once that her brothers had killed him and she started after them.

The boys ran until they came to a river. There they met many white ducks playing on the water. In those days all birds were white. The boys offered to paint the ducks all different colors if they would carry them and their little bob-tailed dog that was with them across the river and not tell any one that they had seen them or helped them across. The ducks agreed, and so the boys painted their feathers. Then the ducks took them on their backs and flew across the stream with them. Soon the girl came along and asked the ducks if they had seen anything of two young men and a white bob-tailed dog. They said that they had not seen them, and the girl was about to turn back when one white duck, whom the boys had forgotten to paint, flew up and told her that her brothers and their dog had just passed, and that the other ducks had lied to her, because the boys had painted their feathers if they would not tell her the truth. The white duck carried the girl across the river and she began again to pursue her brothers. They saw her coming and were afraid that she would overtake them, when they met three white doves. They asked the doves to take them and their dog on their backs and carry them to the sky. The doves agreed and flew to the sky with them and left them there. As the doves were flying down they flew through so much smoke that their white feathers became gray. The girl met the doves and asked them where her brothers and the little bob-tailed dog were. The doves pointed to three bright stars in the southern part of the sky. The girl looked, and when she saw that her brothers and their dog had become stars she fell dead.

12. THE MAN AND THE DOG WHO BECAME STARS.

A young man had a Dog which he always took with him whenever he went to hunt. When he was at home he did not pay much attention to the Dog, and the Dog acted like any other dog, but when they were off alone the Dog would talk to his master just as if he were a man. He had the power of a prophet and could always tell what was going to happen. One time, while they were out hunting, the Dog came running back to his master and told him that they were about to come to a very dangerous place. The young man asked where the place was, and the Dog said that he did not know just where it was, but that he knew it was not far away. In another instant the Dog scented a deer and started out on its trail, and the man followed. Soon they came upon the deer. The man shot it, but only wounded it, and it continued to run until it reached the lake, and then jumped into the water. The Dog jumped in after it and soon caught it, because he could swim faster than the wounded deer. He held it while the young man threw off his clothes and swam to his assistance. Soon they killed the deer, and then the man put it on his shoulders and started to swim to the shore. All at once the Dog cried out, "Look out!" There before them and all around them were all kinds of poisonous and dangerous water animals. The man thought that they would surely be killed, for the animals were so numerous that they could not possibly swim past them. He began to pray to the spirits to help him, and as he prayed the water leaped up and threw them on the shore. The young man felt so grateful to the spirits who had saved his and his Dog's lives that he cut some of the flesh from the deer and threw it into the water as a sacrifice. Then he and the Dog decided that they would not stay longer in this dangerous world, and so they went to the sky to live. There they can be seen as two bright stars in the south. The one to the east is the young man, and the one to the west is the Dog.

13. EVENING-STAR AND ORPHAN-STAR.

A poor orphan boy lived with a large family of people who were not kind to him and mistreated him. He could not go to play or hunt with the other boys, but had to do all of the hard work. Whenever the camp broke up the family always tried to steal away and leave the boy behind, but sooner or later he found their new camp and went to them because he had no other place to go. One time several families went in boats to an island in a large lake to hunt eggs, and the orphan boy went with them. After they had filled their boats with eggs they secretly made ready to go back to the mainland. In the night, while the orphan boy was asleep, they stole away in their boats, leaving him to starve on the lonely island.

The boy wandered about the island, eating only the scraps that he could find around the dead camp fires, until he was almost starved. As he did not have a bow and arrows, he could not hunt, but he sat by the water's edge and tried to catch fish as they swam past him. One day as he sat on the lonely shore he saw a large animal with horns coming to him through the water. He sat very still and watched the animal, for he was too frightened to run away. The monster came straight to him, then raised his head out of the water and said: "Boy, I have come to save you. I saw the people desert you, and I have taken pity upon you and come to rescue you. Get upon my back and hold to my horns and I will carry you to the mainland." The boy was no longer afraid, but climbed upon the animal's back. "Keep your eyes on the blue sky, and if you see a star tell me at once," the animal said to him. They had not gone far when the boy cried, "There in the west is a big star." The monster looked up and saw the star, then turned around at once and swam back to the island as fast as he could. The next day he came and took the boy again, telling him, as before, to call out the moment that he saw a star appear in the sky. They had gone a little farther than they had the day before when the boy cried out, "There in the west is a star." The animal turned around and went to the shore. The next day and the next four days he started with the boy, and each time he succeeded in getting a little farther before the boy saw the star. The sixth time they were within a few feet of the opposite shore when the boy saw the star. He wanted to reach the shore so badly that he thought he would keep still and not tell the monster that he saw the star, for he knew that he would take him back to the island at once if he did. He said nothing, and so the monster swam on until they were almost in shallow water, when the boy saw a great black cloud roll in front of the star. He became frightened and jumped off of the animal's back and swam to the shore. Just as he jumped something struck the animal with an awful crash and he rolled over dead. When the boy came upon the shore a handsome young man came up to him and said: "You have done me a great favor. For a long time I have tried to kill this monster, because he makes the water of the lake dangerous, but until now I could never get the chance. In return for what you have done, I will take you with me to the sky, if you care to go." The boy said that he wanted to go, as he was alone and friendless upon the earth. The man, who was Evening-Star, took him with him to the sky, and there he may be seen as Orphan-Star who stands near Evening-Star.

14. THE GIRL WHO MARRIED A STAR.*

One time a maiden slept in an arbor, and as she lay under the blue sky she watched the stars. One star especially she watched, and she wished that it would become a man and marry her, for she did not care for any of the young men of the village. She went to sleep wishing that the star would marry her. When she awoke she saw no stars, but an old man sitting by the fireside. "Where am I?" she asked. "Your wish is granted; you are the Star's wife. I am the Star." She began to cry, for the man was old and homely and she was young and beautiful, and so she had dreamed that her husband would be. The Star's sister was preparing something to eat, and she told the girl to stop crying and come and eat. After a while the two women went out to dig potatoes. They saw one big potato, and the girl asked the Star's sister what the big potato was for. She answered that it was the door of heaven, and that it covered the entrance to the world beneath. Then the girl cried again and begged the woman to let her go back to her people. She told her how unhappy she was and what a mistake she had made in wishing to marry the Star. The woman told the Star all that his wife had said, and so the Star agreed to let her return to her people in six days. The two women went out to gather bark from young elm trees to make a rope for the girl to climb down to earth on. After they had gathered the bark they began to make the rope and the Star helped them. After six days the rope was only half long enough, and so the old man said she would have to wait six more days until they could complete the rope. On the eleventh day the rope was finished, and the Star's sister cooked some corn meal for the girl to eat on the way and filled a squash vessel with water for her. The Star told her to start early the next morning, for it would take her ten winters and

*Told by Wing.

summers to get to the earth. They fastened her to the end of the rope and then removed the potato and let her through the hole and gradually let the rope slip out. At first she could see nothing but darkness; then after a long time she could see the earth. After she had traveled through many waves of warm and cold air, she knew she had been on her way many summers and winters. Her food was almost gone and still she was a long way from the earth. Suddenly the rope ceased to slip and she hung swinging back and forth. She had come to the end of the rope. It was not long enough. She hung there for a long time and was about to die from hunger and weariness when she saw Buzzard circling around below her. She called to Buzzard to come and help her. He came, and after she had told him her story he told her to get on his back; that he would take her down to earth. Buzzard flew for a long time and the girl was heavy, so that he nearly gave out. He saw Hawk flying below him, and he called Hawk and asked him to help him take the girl home. Hawk flew with the girl until they could see the mountains and the rivers; then he gave out. Buzzard took the girl on his back again, and thanking Hawk for his help, told him to go his way; that he could take the girl on to her home. Buzzard flew on and on until they could see the trees, and soon they were even with the tops of the highest trees. Then Buzzard told the girl to go into her lodge when she went home and not to let any one but her father and mother see her. She was so thin that she was little more than skin and bones. Buzzard flew to the ground and lighted very gently just outside the girl's village. He pointed out her parents' lodge to her and then said good-bye and flew away.

The girl rested for a while and then began to walk very slowly to the lodge, for she was weak and exhausted. On the way she saw a woman coming toward her. She hid behind a bush, but the woman saw her and screamed, for the girl was so thin that she frightened her. The girl told the woman not to be afraid and told her who she was. Then the woman recognized the lost maiden and helped her to her lodge. Her mother did not know her at first, but when she found that the girl was her daughter she threw her arms about her and wept. The news of the girl's return spread throughout the village, but her parents obeyed her wish and refused to let any one see her until after the tenth day. Then they came to her tipi and she told them her story and especially about the kindness shown her by Buzzard.

After that the people always left one buffalo for the buzzards after a big killing.

15. THE GIRL WHO MARRIED A STAR.*

Long ago there lived a large family—father, mother, and eight children, four girls and four boys. They were all beautiful children, especially one of the girls, who was exceptionally beautiful. The time came when three of the girls were married, but the youngest and most beautiful would not receive the attention of any one. The girl was peculiar in her tastes and roamed around alone. She wished to go away somewhere, for she was tired of her home. One time while she was walking alone she began praying to the spirits to help her, that she might go wherever she wished. That night she was outside the lodge watching the stars, and she found that the stars were not all alike; that some were bright and some were very dim. Finally she saw one, the North Star, that was very bright, and then again she began to pray to the spirits to help her, and she wished that she might marry the star and become his wife. She ceased praying and did not know where she was for a while, and the first thing she saw was a very old man sitting by the fireside with his head down. She stood for a long while watching him. At first she could not believe herself, and she thought that she was only dreaming, but finally the old man looked up at her and said: "You are the young woman who wished to marry me and you have your wish; you are now in my home as my wife, as you wished." She did not like the looks of the old man, and she wished that she might get away from him; but her wish was not granted and she had to stay. She tried many ways to get away, but all failed, and she was about to give up when she thought of a great big round stone that the Star had told her not to move, for it was very dangerous to move it. One time when the Star was away on a visit she thought she would go over and lift the stone and see what was there. She lifted the stone and found that she could look clear down to the earth, and then she began to wonder how she could get down to the earth. She put the stone back in its place, and when the Star came back he asked her where she had been, and she told him that she had been at home all the time. When night came she went to bed, and as she was wondering how to get down to the earth she thought about making a long rope out of soapweeds, for she had heard the old story about the people making such a rope long ago. When the Star went away for his nightly trip she would go out and cut soapweeds; but when he came back he would always find her at home, and so he never thought of her doing anything of the kind. Finally she had enough weeds cut, and then she began to make the rope. It took her a long while before she had the rope finished.

*Told by Annie Wilson.

One day she thought she had rope enough to reach down to the earth. She went and lifted the stone to one side and dropped the rope down just as fast as she could. She finally came to the end of the rope; then she fastened it to the rock and placed the rock over the hole again and went back home. When the man came she was at home, but the next time he went away she went to the hole and began to climb down. It took her a long while before she could see the land plainly, and before she came to the tops of the trees she came to the end of the rope, and she did not know what to do. She was getting very tired, but she hung there for some time, and after a while she heard a noise near her and she looked and saw a bird. The bird passed under her feet several times, and when he passed the fourth time he told her that he would take her down and carry her home if she would step on to his back. She stepped on the bird's back, and he asked her if she was ready, and she said that she was; then he told her to let go of the rope. She did so, and the bird began to fly downward very easily. The bird asked if she would let him take her on to her home, and she said that she would. The bird then took her to her home, and when they came near, the bird let her down and told her that he had to go back to his home; but before leaving her he told her that he was Black Eagle.

16. LIGHTNING AND THE PEOPLE.

In the beginning Lightning lived upon the earth with the people, but he became so powerful and killed so many of the people that they feared and hated him. One time after he had become angry and killed a number of the people, the chiefs of the tribe called a council to determine what to do with him. They decided that he could no longer live with the people, but would have to go away. Lightning pleaded to stay, but the chiefs would not change their decision and told him that he would have to go.

Not long after Lightning had gone a great monster that lived underground among the rocks began to carry away the people. They tried in every way to kill him, but could not, for he always disappeared under the ground where they could not reach him. Lightning appeared to them and told them that he would kill the monster if they would let him come back and live with them. He said that he wanted to come back to earth, and that he would kill all monsters and make the earth a safe place for the people to live on, and would not do any more harm himself if they would let him come back. The people decided to let Lightning come, because there was no one else powerful enough to kill the great monster.

17. THE BROTHERS WHO BECAME LIGHTNING AND THUNDER.*

When the world was new there lived among the people a man and his wife and one child, a boy of about twelve years. The people called the man "Medicine-Man." Now and then he went out on the hunt, and never was known to come home without killing a deer, and almost every time he came home with a big buck. One time when he was out hunting he killed a deer and then started back for home, and when he reached home he found his little boy there alone and not as usual, for he looked weary and frightened. When his father asked him where his mother was he began to cry and said he did not know; that all he knew was that she took a water bucket and went down toward the creek. He said that he had run over there two or three times calling his mother, but no answer came. Then both the little boy and Medicine-Man went down to the place where the woman usually went to get water, but they could not find her. They found foot-prints at the edge of the water, and then the Medicine-Man knew that his wife and the mother of his only child was dead and gone; that something had taken her life; so they came back to their home and mourned for her six days. They built a fire and watched it and stayed by it for six days and nights.

The seventh day Medicine-Man told his son that he was going hunting, for their meat was about out. He went out to hunt and the little boy stayed at home alone. While his father was gone the boy would play around the house, shooting with his bow and arrows. When Medicine-Man came home he found his little son there waiting for him. Medicine-Man went out to hunt the second and the third time and found the boy safe on his return. The fourth time he went out. While he was gone the little boy went out to play. While he was shooting with his bow and arrows he saw some one coming toward him. He was not a man, but a boy of his own size, and had with him a bow and arrows. Medicine-Man's boy was afraid of him, and was about to run and cry when the unknown boy spoke to him, saying: "Don't be afraid of me, brother; I know you don't know me. I am your elder brother." The unknown boy looked queer to him. He had a rather long nose and very long hair, but Medicine-Man's boy was not afraid of him since he had spoken. He continued: "I know you are lonely; that is why I thought of coming down here to see you. Every time our father goes out for a hunt I will come to see you, but you must not tell him that I came to see you while he is gone. Say nothing to him about me. Now, brother, let us see who is the best

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* Told by Wing.

shot with the bow and arrows." They began to play. Finally he said to his brother, "Father is coming and I must go," and he ran back to the woods. Medicine-Man was far from home when the boy saw him coming, and when he came the boy was gone, and his son did not say anything about his having been there.

Again Medicine-Man went to hunt, the second time and the third and the fourth time. When he came home in the evening after he had been out the fourth time the boy seemed troubled. They ate and then went to bed. About midnight the boy woke up and thought of his secret brother, and he thought at once that he must tell his father about his brother. He woke his father and said: "Father, I have something to tell you, although I was told not to say anything about it to you." Medicine-Man gave very close attention. "Father, somebody comes here every time you go out to hunt, and he is not very big; he is about my size. When he first came he frightened me and I started to run, but did not know where to go, and I began to cry and the boy told me not to be afraid of him, for he was my brother. He has a long nose and wears long hair and has a bow and arrows, and we always play around here every time you go out to hunt and he treats me kindly. He seems to see you, no matter where you are, and when you start home he knows when you are coming, and then runs for the woods, and when you get here he is gone." "Well, my boy," said Medicine-Man, "we must capture the boy some way. You must go out there and play just as if I had gone away again, and whenever he asks you where I am, tell him I am out hunting. I will turn into a very small insect and stay behind the door."

The little boy ran out next morning with the bow and arrows and began to play at the usual place. Finally the other boy came, but before he came near he spoke and asked Medicine-Man's boy where their father was, and the boy said that he had gone out hunting again. The boy began to look around, and finally he said: "Who is that man behind the door?" at the same time running back to the woods.

Again the next day the boy went out to play; this time Medicine-Man placed himself at the edge of the roof of the grass house. When the boy came he asked his brother where their father was. He answered that he had gone out hunting, but the boy would not come near. He began to look around, and finally he said: "Who is that man under the roof?" and he ran back into the woods again. Then Medicine-Man said: "We must catch him some way. When he sits down near to you, tell him that something is crawling in his hair, and then he will let you look in his hair. Then catch hold of a small bunch of his hair and tie it up four times; then call me and I will be there just as soon as I can. You must not let him go until I get there." The little boy understood.

The other boy had already run away twice and this was the third attempt. This time Medicine-Man placed himself in the middle of the fire. The boy went out and began to play. Soon the other boy came. He asked the boy where their father was and he told him he went out to hunt. The unknown boy began to look around, and finally he said: "Who is that man in the fire?" and then he ran back to the woods. The next day the boy went out and began to play and the unknown boy came again, and asked the boy the same question. The boy answered that their father had gone out to hunt. This time Medicine-Man had placed himself behind another door, and the unknown boy found him again and went back to the woods. And so the fifth time came, and this time Medicine-Man placed himself in the air, and when the unknown boy came he found him again and went back to the woods.

Medicine-Man tried once more. If he failed the sixth time he could do nothing more, for he would have used all his powers. He told his boy to go out again to play as usual, and this time his own boy did not see which way he had gone. Finally the other boy came and asked where their father was, and he told him that he was out hunting. This time the unknown boy believed him, and so he came near and sat down by him and the little boy got hold of his hair and said: "There is something crawling up in your hair, brother," and then the boy told him to get the bug out of his hair; and the boy began to do as he had been told, and when he got through he called out, "All ready, father." Medicine-Man jumped out from the grass house, and then they captured the boy and took him into the grass house and held him there for six days. At the end of the sixth day the little boy boiled some water and they washed the other boy, and Medicne-Man cut his nose off and made it look like a human nose. Medicine-Man said: "You have been coming here when I am absent and have been playing with my son and you call him brother. Now you may be his brother and stay with him and go out and play with him." The boys went out to play, and before Medicine-Man went to hunt again he went over to see the boys and told them he was going to hunt, and told them to stay at home and not to go to a certain place in the timber, where some very large squirrels lived, for they often killed little children. After their father was gone the unknown boy told his young brother they would go there and see the squirrels, and so they started. They could not find the place for a while, but finally they did, and they stood there for a good while watching the big hole in the tree.

After a while one of the big squirrels came out, and sticking his tongue out like a snake, took the younger brother into the tree. The other boy stood there watching the squirrel take his brother into the hole. He did not try to help his brother, for he knew he could get him out of the hole whenever he wanted to. After the boy had disappeared he went back to their home, and when he got there he found their father already returned from the hunt. The father asked him where his son was, and the boy told him that his brother and he were making lots of arrows, and that he came home after fire to dry the arrows with it. He took the fire and carried it to the timber, where he placed it near the tree where the large squirrel was. Then he brought some hard, red stones and put them in the fire, and when the stones were very hot he took one of them and threw it into the hole, and then another one. While he was standing there watching the hole he saw the large squirrel come out from the hole and drop down on the ground dead. Then he went over and cut the squirrel's stomach open and found his brother in there, still alive. He took him down to the river and washed him and then they both went home.

Sometimes these two boys would go out to make arrows. One time when they went out the unknown boy made two arrows for his young brother; one he painted black and the other he painted blue. They made a small wheel out of bark of the elm tree. One of the boys would stand about fifty yards away from the other, and they would roll this little wheel to each other and would shoot the wheel with the arrows. They played with the wheel every day until finally Medicine-Man's boy failed to hit the wheel, and the wheel kept rolling and did not stop until it went a long way from them, and they never found it again. The boy felt very bad, and he wanted to get the wheel back, and so the unknown boy said: "Don't worry, brother, for we can get the wheel back again." And so they started out, and they did not let their father know where they were going, nor how long they would be away from home. They went a long way and they could see the trace of the wheel all the way. Finally the unknown boy said: "Well, brother, we are about half way now, and we must stop for a rest." They began praying to the spirits to help them. The unknown boy had two pecan nuts, and he told his brother to watch, that he was going to put one of the nuts in the ground. Then they began to pray again, and while they were praying the pecan nut began to sprout, and it grew taller and larger. Finally the tree grew so tall that it went clear up into the sky, and then the unknown boy told his brother that he was going up on this tree, and that he must sit near to the tree, but must never look up to the sky, but down on the earth, and that he was going to be gone for a good while, until he dropped all the bones that he had in his body; that at the last he would drop his head, and then the boy must gather all the bones up, put them on a pile, cover them with buffalo calf's hide, take the black arrow and shoot it up just as hard as he could, and when he heard the arrow coming down to tell him to get out of the way, that the arrow was coming right on him, and that the pile of bones would get out of the way. Then he started climbing up the tree and the little boy sat on the ground looking down. After quite a while he saw one of the bones drop, and then another and another, and so on until all the bones had dropped, and then he gathered them up and piled them together and covered them with the buffalo calf's hide. Then he shot the black arrow just as he was told, and when he heard the arrow coming down he cried out: "Look out, brother, the arrow is coming down right on you. Get out of the way." His brother jumped out from the buffalo calf's hide, and the arrow struck right where the hide was. He said, "My father gave me very dangerous power, and so, brother, you must climb up the tree and he will give you power, too." The little boy climbed the tree, and he went clear up as far as the other boy had gone. He did not know where he was, and it seemed like a dream to him, and when the bones began to fall from his body he did not know it. All he remembered was that there was some one talking to him, but he did not see who it was, and the next thing he heard was, "Look out, brother, the arrow is coming right down on you. Get out of the way." He jumped out of the way and saw his brother standing there. His brother asked him what kind of a power he had received, and he told him that it was a great power. The boy told his brother to show him what kind of a power he had, and then the little boy began making a loud noise that sounded like thunder when it rains, and then the unknown boy let his tongue out and it looked like a flash of lightning.

They went on until they came to a large lake, and when they looked near to the edge of the water they saw the trace where the wheel had passed into the water, but they could not find any place to cross. They sat down on the bank of the lake and began to pray again, and the boy planted another pecan nut, and soon a large tree sprang up; but this time the tree did not grow upward, but bent over across the lake to the opposite bank, and so made a bridge for them to cross upon. They went across the lake, and when they got across they saw the trace of the wheel, and a little way from the landing place they saw a narrow road leading toward the east, and a little way from the end of the road they saw that the trace of the wheel was gone. A little way from there they saw an old man going toward the lake, and then the boy who had the power of lightning said: "We must kill this man, because we know he is a bad man; he is a cannibal." When they met this old man Lightning boy said to Thunder boy: "This is the old man who took our wheel, and he has it with him now, and it is in his right side." They killed the old man and found the wheel and took it, and then they went on and they saw, a long distance from them, a smoke, and they went there and found many people. The people did not know who they were at first; they thought they were the old man, for this old man whom they had killed was their head man; and so these two brothers killed all the rest of the people. They began to look all around and finally they came to a pile of human bones. They found the bones of the wife of Medicine-Man. Only one little finger was missing. They piled the bones together and covered them with the buffalo calf's hide, and Lightning boy shot the black arrow up, and when they heard the arrow coming down they said: "Look out, mother, the black arrow is coming right on you. Get out of the way," and the woman jumped out of the way. The boys greeted their mother, and then they all started back for their home, and when they came near to their home Lightning boy said that he was going on ahead. The other boy and his mother came on behind. Lightning boy got there first and found their father a very old man, and still weeping for his children. The yard around the grass house was overgrown with tall trees and weeds and grass, for the old man was not able to work any more. Lightning boy told him that his son and his lost wife were coming. The old man was glad, and went out to meet them. They all lived happily for a number of years; then the father and mother died. The boys were lonely then, and so they decided to leave this world. They went up in the sky, and now when the clouds gather together for a storm Lightning and Thunder, which are these two boys who once lived on the earth and killed the monsters that lived here, are seen in their midst.

18. SPLINTER FOOT BOY.

An orphan boy who lived alone with his grandmother was a famous hunter and often went out on a long hunt with his friends. One time, while they were a long way from home, the boy was wounded by a stick that pierced his leg and broke off inside of it. His leg festered and swelled up so that he could not walk and his friends had to carry him home. His leg continued to swell until it was as large as his body; then the skin broke, but instead of the stick coming out, a child came. The boy was angry and would not look at the child or have anything to do with it. His grandmother took pity upon the baby and cared for it.

One day while she was away the boy took the child and carried it to the lake, where he left it to starve or be eaten by the wild animals. He was afraid to return to his grandmother's home for fear she would know that he had thrown his child away, and so he went far off and lived alone. The child lay on the shore of the lake for a long time, and as he lay there he grew to be a good-sized boy. Finally many birds flew over the lake, and when they were about half way across the lake, the water appeared to leap up to the sky and draw the birds down. Every day the boy saw the water leap up to the sky whenever any birds flew past, and one time he saw a big water monster in the water. He saw the monster draw so many birds into the water that he was afraid it would kill all the birds in the land, and he wished that he could kill it. While he was thinking about a way to kill the monster, he felt some one hit him on the back. He turned around and there behind him stood a boy about his own age. He was Medicine-Screech-Owl, but the boy did not know who he was or anything about him. Medicine-Screech-Owl asked the boy what he was thinking about, and the boy told him that he was thinking how he could kill the water monster that ate up all of the birds. Medicine-Screech-Owl told the boy that he would help him kill the monster. He showed him where the old woman, his grandmother lived, and then he told him to go to her house and get six arrows and a bow and six grains of corn from six kinds of corn and then return to the lake.

When the boy went to the old woman's house she was surprised and happy to see him, for she had been very lonely since the orphan boy and his son had disappeared, and had given up all hope of ever seeing them again. The boy told her what he wanted, and she gave him all he asked for. Then he returned to the lake, where he found Medicine-Screech-Owl waiting for him. Medicine-Screech-Owl took three grains of each of the six kinds of corn and threw them into the air. They became birds and flew out across the water, and the water monster leaped up to draw them down. As he leaped up Medicine-Screech-Owl cried to the boy to shoot it. He shot the first arrow, but it did not go near the monster. The second went nearer, and so did the third, fourth, and fifth, and the sixth pierced it through. The great monster rolled over on its side and floated on the water, and then they could see how large it was. Medicine-Screech-Owl said that it was the largest water monster in the world. He told the boy to take his bow and pull the animal to dry land, but the boy knew that he could not move the monster with his little bow, and so did not try. To his surprise Medicine-Screech-Owl took his bow, that was even smaller, and pulled the great monster to the bank. When he had done this he disappeared, and then the boy went back to his grandmother's house and told her about the boy he had met at the lake and how they had killed the big water monster. The old woman knew that the boy's companion was Medicine-Screech-Owl, and she also knew that he had given the boy wonderful power, though she said nothing.

The next day the boy went to the lake again. He found the water very low, since the monster had been pulled out of the lake, and it was so clear that he could see many fish swimming about. He dived down to catch some of the fish, and a big sword-fish swam up to him and went right through him. The boy, though severely wounded, did not die, but shot the fish with his bow and arrow. The next day he again went to the lake to fish, but found that all the water had gone. In the mud he saw two large shells. He carried them home and cut them so that he could put them over the holes that the sword-fish had made when it cut its way through him. He wore one in front and one behind, so that no one could see the wounds that the fish had made. The shells had the power to hear any sound in the whole world, and whenever he wanted to hear anything he removed the shells from the holes and put them to his ears. With the power of hearing every sound in the world and the power given to him by Medicine-Screech-Owl, he became a great medicine-man and the people began to fear him and planned to kill him. When he heard that they were going to kill him he told his grandmother that they would leave the people, but that he would do them harm some time because they had planned to kill him, and so made it necessary for him and his grandmother to leave. They went to a high mountain near the village, and made their grass house on the very top of it. He found two fierce dogs and placed them at his door to guard the house.

The boy knew who the people were who had planned to kill him, because he had heard them talking by means of his wonderful shells. Soon they died, one after another, until the people of the village began to suspect that the boy was bewitching them and causing them to die. Many of the warriors tried to steal up to his home on the mountain and kill him, but with the magic shells he could always hear them coming, and would set the dogs on them, so that they could never approach.

He kept on bewitching so many people that finally Medicine-Screech-Owl decided that he would have to interfere. He started up the trail to the boy's house, but first he blew his breath so hard that it took the magic power of sound from the shells, so that the boy could not hear him coming. When he was almost at the top of the mountain he blew his breath again and the dogs rolled over asleep, and when he passed them they were so sound asleep that they did not wake up and bark or give any warning of approach. He passed the dogs; then he blew his breath again and the old woman fell over asleep. Again he blew his breath, and the boy fell down asleep. Medicine-Screech-Owl then entered the house and took the shells off of the boy. He walked around, looking at everything, then went away. When he was almost down the mountain he blew his breath and the boy woke up. He missed his shells at once and began to look everywhere for them. He called his grandmother to come and help him look, but she did not wake up. Finally he shook her so hard that he shook all of Medicine-Screech-Owl's breath out of her, and then she woke up and helped him look for his shells. He went outside and found the dogs asleep; then he knew that some one had been to his house and stolen his shells. He called the dogs, but could not wake them, and so he took a club and knocked the breath out of them. They woke up and at once scented Medicine-Screech-Owl's tracks and started after him. The boy followed, and they soon came to a big circle of fire. In the midst of the burning circle stood Medicine-Screech-Owl, and he was wearing the shells. The boy had no power that would take him through fire, and so he had to return without his shells. Medicine-Screech-Owl kept the shells for some time, and then he took them back to the boy, but before he gave them to him he made him promise that he would not bewitch the people any more.

19. MEDICINE-SCREECH-OWL.*

Medicine-Screech-Owl was born at Long-Timber-on-the-Top-of-the-Hill. His father and mother were very old and lived near the center of the village. When his first birthday came he was given bow and arrows. His father and mother were asking each other what name they should give to their child, but before they could name him he spoke and said, "My name shall be Medicine-Screech-Owl." His mother scolded him, because at this time there was also a man by the name of Medicine-Screech-Owl, and he was an ex-chief; but he said that he would have no other name, and so his parents named him Medicine-Screech-Owl. One night some one passed near the village and heard the child's mother calling him by the name of the ex-chief. When the man came to the ex-chief's place he told him that the child's name was the same as his. When the ex-chief heard this he was angry, and told the people that he was going to kill the boy if he did not do as he should tell him to do. He sent for him, and when the boy came to his lodge he gave him watermelon seed and said: "Go back and plant this watermelon seed this evening. In the morning go and

*Told by White House (Caddo Jack).

bring to me a great big watermelon to eat." "All right," said young Medicine Screech-Owl. He took the seed, went back to his village, and told his father and mother what the ex-chief had told him to do. That evening the boy went out a short distance from his lodge, threw the seeds upon the ground, and there sprang up a large watermelon plant. He then went back to the lodge and told his father and mother what had happened. Early in the morning he went out to his watermelon vine, and he found many large watermelons on it. He took one of the melons to the ex-chief, who was surprised, and he thought that surely the boy was going to be a wonderful man. He was so jealous of him that he determined to destroy him, for he thought that if he did not young Medicine-Screech-Owl would get ahead of him in every way, and that the people would no longer pay him any attention. The boy went back to his village and told his father and mother all about what had happened. The ex-chief sent for the boy the second time, and the boy again went to his lodge. The ex-chief had brought the boy a large bull to milk. He told him to take the bull to his lodge and to bring the milk over the next morning. The boy took the bull over to his village, but instead of milking it when morning came he took an axe and went out near the ex-chief's lodge to chop some wood, and when the ex-chief saw him chopping wood he went to him and asked him if he had already milked the bull. The boy told the ex-chief that he had not milked the bull, but that he was in a hurry to cut some wood to take home. The ex-chief asked him why he was taking the wood home. "Well," said the boy, "my father is going to have a child." The ex-chief laughed at the boy and asked him if he ever had seen a man have a child. The boy said, "No; I never have." Then he asked the ex-chief if he ever had seen a man milk a bull or a bull give milk. The ex-chief was very angry. The boy returned to his lodge and told his father and mother what had happened. The third time the ex-chief sent to have the boy come over to his lodge, informing him that he and some of his friends were going to have a fine time and a big dinner. In the meantime the ex-chief and the others were digging a big hole in the ground, in which they were going to throw the boy. They dug the hole about fifty feet deep and about four feet in diameter and covered it with a buffalo robe. When the boy came the ex-chief told him that he had already fixed a place for him to sit. Young Medicine-Screech-Owl never left his bow and arrows, but always had them with him everywhere he went. When he entered the ex-chief's lodge they told him to be seated. He laid down his arrows and bow and went and sat down on the hide, and down he went into the hole. The ex-chief was very glad, for he thought surely he had killed the boy. He commenced filling the hole with heavy stones and dirt until he supposed that the boy was dead.

One evening the same person, who had passed the lodge and heard the boy's mother calling him by the ex-chief's name, passed again, and again heard her calling the same name, and he heard young Medicine-Screech-Owl answering her. The man went to the ex-chief's lodge and told him that the boy was still living, because while he was passing by his lodge he had heard his mother calling him and had heard him answering. When the ex-chief heard this he became very angry, and said that he was going to try once more, and if he failed to kill the boy this time he would leave him alone. He sent for the boy the fourth time. He came, and found that they had built up a big fire. The ex-chief told the boy to go right into the middle of the fire and sit down, for he wanted to see if he had any powers at all; that if he had any powers he would not burn up. The boy went into the midst of the fire and sat down for a long time, until the fire burned out; then he arose unharmed. When he had come out of the fire he made another big fire and told the ex-chief that it was his turn to go into the fire, to show whether or not he had any power. The ex-chief went in and the fire burned him to death.

From that time on the boy would go from place to place. Finally he grew to be almost a man in size. Many times he would run away from his father and mother, and when he returned his mother would scold him. Still he continued to go off wherever he pleased. The reason why his mother scolded him so much when he went anywhere was because she knew that there were many people who were envious of his power and would try to kill him; but the boy did not care for that. There was one place where three of his enemies were living, who were always talking about killing him. Medicine-Screech-Owl heard these men talking about him, and so one day he determined to visit them. He quietly stole away from his father and mother, for he dared not say anything to them about going, for fear they would not let him go. When he came to the place he found the three men at home, and when they saw him coming they all came out from their lodge and were very glad to see him, for they had been wishing for a long time that he would come. They asked him where he was going. He replied that he had come over for a visit to his friends. They asked him to go into the lodge. Young Medicine-Screech-Owl knew that he was to go in first, and that all the others would come in and attempt to kill him. The door they had to enter was very small, although big enough for one man at a time to enter. When Medicine-Screech-Owl had entered he stood by the door and waited for the others to come in.

His only chance was to kill them. He stood by the door waiting and ready to strike the first to enter. As the first man entered, he struck him on the head and killed him, then pulled him in just as quickly as he could, to make it appear that the man had entered without anything happening. Thus he killed the second and the third man. Then he returned home and told his mother and father all that had happened.

Another time there was a man called Snow-and-Cold, living with his family far away in the north. When anybody went over there on a visit and happened to stay over night, he would be frozen before morning. Medicine-Screech-Owl heard all about this man and made up his mind to go and visit him and his family. One day he started out. It took him a long time to reach the place, for he had to go across a large lake. When he came to the water he stood on the edge of the bank. He wore on his head an eagle feather, and he took the eagle feather off from his head and placed it on the water and placed himself on the eagle feather. The feather began to sail across the water. On the other side of the water were many geese, and when any one came across the water the geese would make so much noise that the people at the home of Snow-and-Cold would know at once that somebody was coming. When young Medicine-Screech-Owl went across to visit old man Snow-and-Cold the geese did not see him when he landed on the other side. He stepped off from his eagle feather and placed it on his head again and walked straight to the place where Snow-and-Cold lived. All this time nobody had seen him. Medicine-Screech-Owl went into the lodge where Snow-and-Cold was and found him lying down, asleep. Medicine-Screech-Owl spoke to him and asked him how he was getting along. When Snow-and-Cold awoke he looked around, but could see no one. Again Medicine-Screech-Owl spoke to him, and this time Snow-and-Cold arose from his bed and began to look around. He could find no one in the room. When he started to lie down again Medicine-Screech-Owl spoke to him and showed himself. Snow-and-Cold was surprised to see Medicine-Screech-Owl there and asked him what he wanted. Medicine-Screech-Owl replied that he had come over on a visit, because he had heard so much of the place. When evening came Snow-and-Cold told the boy to sleep right there, in a bed which had nothing but snow on it. After they had gone to bed Snow-and-Cold did not go to sleep, but kept watching the boy, for he thought he would surely freeze to death in a little while; but every time Snow-and-Cold looked over to see him he would see a light right next to his head. He wondered what it could be. Medicine-Screech-Owl had his feather sticking straight up on his pillow during the night. Snow-and-Cold arose, reached for the cane which e had placed at the foot of his bed next to a place that seemed like a fireplace. Medicine-Screech-Owl watched him all this time, but he did not know that he was being watched. Snow-and-Cold took the cane and punched the snow where it seemed like a fireplace, and the fire sprang out from the snow. When he had warmed himself he covered the fire and went back to his bed. Soon he saw Medicine-Screech-Owl get out of his bed, go for the cane, and punch the place, and out came the fire. When Medicine-Screech-Owl was through warming himself he walked back to his bed. Snow-and-Cold did not know what to think of Medicine-Screech-Owl. The next morning Snow-and-Cold called to Medicine-Screech-Owl to get up from his bed. He thought he had been frozen to death, but the boy jumped up and said that he had had a fine sleep. After he was through talking to Snow-and-Cold he said he would have to go back home; that his mother would not like it if he should stay out another day. He started back, and when he reached home he told his mother all about it.

20. MEDICINE-SCREECH-OWL.*

In a village there lived an old man, his wife, and one child, a beautiful girl. The girl had never been known to have a male acquaintance, and was always modest and well-beloved. Nevertheless, in some way she became pregnant. Her father and mother noticed this and called her attention to the fact, and asked her how it had happened and who was the father of the child. In those days it was the custom to find out all about such matters. The girl herself did not know how she had come to be in that condition and could not answer their questions. Her people were angry at her and much ashamed, but could not get her to answer any of their questions. She went as usual with the girls of the village to dig potatoes, but she could never find any and always returned without any. One time, after her mother had scolded her for never bringing home any potatoes, she was wandering slowly about trying to find some when she heard a voice cry, "Mother." She looked about, but could see no one. Again she heard the cry, and then she knew that it was the child in her womb that was crying. The voice told her to go to a certain place and dig. She obeyed and found many large potatoes. When the other girls saw them they wondered, for they knew that she was never successful in finding them.

The child was born and, at his own request, was called Medicine-Screech-Owl. The mother and child lived apart from the others and were very poor and often hungry, for they had no one to hunt food for them, and all they had to eat was what people gave to them. The child grew rapidly and was soon large enough to play with the other

* Told by Wing.

little boys. There was a lake near the village where the men fished, and the children were accustomed to go to the lake and watch them. One time Medicine-Screech-Owl asked his mother if he could not fish too. She only laughed at him and told him that he was too little; but he begged so hard that she finally said he might go and try. He went, taking his little bow and arrows, and soon returned with a big fish. His mother was greatly surprised and gave her consent for him to go the next day. Again he came home with a big fish, and again and again, until his fame as a fisherman spread throughout the village.

There were many who did not like the boy because they did not know who his father was, and when they heard about his success they began to fear him and decided to kill him. There was among the people a powerful Medicine-Man, and they asked him to use his powers against the boy and kill him.

One day, while the boy was at the lake fishing, he saw the reflection of a big, black cloud in the water. He knew that the Medicine-Man was sending Thunder to try to kill him, but he did not fear. He walked into the water until it was up to his knees. Then came a peal of thunder and a shaft of lightning. He raised his bow over his head and the lightning rolled from it into the water. Again and again the lightning shafts struck at him, but every time he caught them on his bow and hurled them into the water. At last the Medicine-Man realized that the boy had more power over Thunder than he had, and so he gave up. That evening the boy returned home with a big fish and told his mother what had happened.

Nothing more happened for a long time, but one day while the boy was lying in his lodge resting it occurred to him that something was going to happen to him. He arose from his bed, took his bow and arrows, went back to his bed, lay down and began to sing. Soon he heard a great noise, and he knew that the Medicine-Man was sending Cannibal monster to destroy him. He heard the monster's roar, that sounded like thunder, but he lay still and sang as though he had nothing to fear. As the monster came nearer he could feel its hot breath, but he did not move until it leaped upon his lodge and fell through with an awful crash. Then he arose and killed it.

After that Medicine-Screech-Owl started out to travel, and he went from place to place, killing monsters and ferocious animals and healing the sick. Where he was, death could not come, and so powerful was his touch that people were healed if he placed his hand on the diseased place. Finally, after he had been with the people for a long time, he called them together and told them that he was going to leave them. He disappeared and has not been seen since.

21. THE ORPHAN BOY WHO BECAME A WRESTLER.*

A boy lived alone with his old grandfather. His mother and father died when he was only a baby, and there was no one to care for him but his grandfather. They lived together, and the old man cared for the child as best he could until he had become old enough to play around. The grandfather was looking forward to the time when he could make bows and arrows for the boy and teach him to hunt, but before that time came the old man died and the boy was left alone. He went from lodge to lodge and begged, and whatever the people gave him he ate and was grateful. At night he returned to his lonely lodge and cried, for he was poor and alone and afraid. The boys of the village came to his lodge to see him, and they teased him and laughed at him because he was sad and did not know how to play as they did. He was brave and did not lose courage. When he was larger he made himself a bow and some arrows and went out to hunt. He brought back small game at first and was happy, because he no longer had to beg.

One time when he was out alone far in the timber he heard a voice singing and calling to him to wait. He waited and a strange boy came running through the bushes. The stranger was homely, but so full of fun and energy that the poor orphan boy determined to make him his friend. They played together, and finally they tried to see which was the stronger. The stranger looked much stronger than the orphan, but, to his surprise, he found that he could easily throw him. The orphan boy could not understand how he could throw the strong-looking boy so easily, for all the boys in the village made fun of him because they could so easily throw him. The strange boy arose and smiled and said: "I have given you my power. I am a wonderfully strong man. I have given that power to you. Now you can go back to your village and throw any one you please. I have been watching you and seeing how the boys teased you. I have decided to give you power. Now you are one of the strongest men in the world and can throw any one."

The stranger disappeared. The boy lay down to rest, for it had grown dark and he could not find his way home. The sun arose and the boy waked and started on to hunt. He killed three deer and started home with them. His load was heavy and he could not go fast. When he was far from home darkness came again. He lay down on some soft grass to rest until daylight. Soon he heard a voice, and looking up he saw the same stranger who had appeared to him the night before. The

* Told by Wing.

stranger asked the boy if he would not go to the meeting place where he and all his friends met to wrestle. The boy said that he would go. The stranger helped him carry his meat, and soon they were at the place. There were many boys and men there. One stepped forward and asked the orphan boy to wrestle with him. The boy easily threw him. A second, third, fourth, and fifth came forward, and he threw one after another. Then the strong men began to fear the boy, and they all went away and left him alone with only the one who had given him the power. While they sat down to rest, the strong man told the boy more things about the wonderful power he had given him and how to use it. When the sun arose the strong man disappeared and the boy took up his meat and returned home. He had been home but a few days when it was noised about the village that the boys were going to have some wrestling matches. He went to watch the wrestling, but stood far out from the ring among the spectators. Soon a young man from the ring called him to come in, if he were not a coward. He only shook his head. Again the young man called, not thinking that he would come, but only to tease him. The boy at once threw off his blanket and ran into the ring. In a short time he threw the man and killed him. Then he asked for another to come and fight with him. None came. All were afraid of his great strength. The report of his deeds soon spread among the people, and it was not long before he had the respect and fear of all.

22. THE DANGEROUS WATER MONSTER.*

When the world was new and not well known it was a dangerous place to live in. One time when there were many people camping near a small creek one of the men went down to the creek to get water. After he had finished drinking he looked into the water and saw a large animal that looked like a snake. It was slowly moving up the creek and he saw that it was very long. He ran up the creek to see how long it was, and he ran about two miles before he came to its head. Then he started for the camp, and when he arrived he went to his grandfather, who was always at home, because he was a very old man and could not hunt with the others. He told him what he had seen, and when he finished telling him the grandfather said: "You have seen some wonderful thing, my son, that has been sent as a sign to our people." He did not know what the sign was and so he called for the errand man, and when he came the old man told him to call all the people together at his lodge, for he had something to tell them. When the people came in he at once told them about what his grandson had seen. Some of the men would not believe him,

* Told by Wing.

but most of them went down to the creek and there saw the water monster and knew that the man had told the truth. They all wondered why it had come and whether it was a good or evil omen. The old men tried to recall the past, to find out if the people had ever had a similar sign sent to them, but could not remember any. There was one man in the camp who was old and blind, and he knew many wonderful things; and so the people went for him, and when he came the chief asked him if he knew what the appearance of the water monster meant. The old man sat there for a while without a word, and every one was very quiet. "Well," he said, finally, "the sign is a very bad one, for it signifies that the waters shall rise in a short time." It was not long until the waters rose and formed a large lake. The lake was very dangerous. When one crossed it he had to cross without saying a word to any one.

One time there were four men who went out hunting on the other side of the lake, and after they had killed much game they started back again. They crossed the lake without making any noise and were within a short distance of the opposite shore when one man, who was very brave, thought he would see what the water would do to them if he spoke. He began to talk very loud, and in a little while the water rose up in a cloud over their heads and they were all drowned but the one man who had told that the water was very dangerous and warned the man not to talk. He went home empty-handed, for his bow and arrows had been washed away. He called some other men together and told them what had happened and asked them to go with him to search for the bodies of the men. Two of the bodies were found, but the body of the man who made the noise could not be found.

23. SLAYING THE MONSTERS BY FIRE.*

In the olden time the world was full of all kinds of wild animals who ate people and tame animals. In those times Coyote called all the people together to a council to see what could be done with the wild animals, because they were getting so bad that the people could not go away from their homes to hunt food or to visit each other. At the council they decided to set fire to all the grass, which was as high as trees, and so burn the wild animals and everything on the earth. They chose White-Headed-Hawk and Crow, because they were the swiftest of all the people, to fly to some bright Star and tell the Star that they were coming to his home to live. The Star told them that there was room for the people in the heavens if they could get up there. The messengers returned and reported to the people. They decided to make a long

* Told by White-Bread.

rope out of soapweed and go to heaven on that. They began to gather the soapweed and twist it into a strong rope. The rope was finished; then White-Headed-Hawk and Crow took it and again flew to the heavens. They gave the end of the rope to the Star, who put one end of it under a big stone and let it hang down. It was so long that it reached the earth, and the people saw it hanging ready for them to crawl up when the time came. They appointed two men, Gray and Black Snakes, to carry the fire over the world. One was to carry the fire to the east, then to the south; the other was to carry it to the west, then to the north. Soon the people noticed a cloud of smoke, and then the sun began to fade and look dim, and a great noise of all the wild animals arose. The people saw the fire coming nearer, and so they began to climb the rope. After all the people were on the rope and had climbed up a little way the wild animals came and began to climb up. The people saw the animals coming up, and so they appointed Bat to cut the rope just above the wild animals, and they gave him sharp teeth to cut the rope with. Bat began to fly around as though looking for a place on the rope to stay. Finally he asked the first wild animal to let him in by him, and he did. After a while the animal noticed that Bat was eating something, and he asked him what it was, and Bat said that he was eating a parched grain of corn that his grandmother had given him. He kept on chewing the rope when the animal was not looking, and finally the rope broke and let all of the wild animals down and many were killed. Bat went down to make sure that all were killed or burned. He saw an immense animal on the ground and all the other animals crawling into it to escape the fire. Bat went into the animal's nose and pulled out some hairs. This made the animal sneeze and blow all of the other animals out and they burned to death. Bat flew up to tell the people that all the wild bad animals were killed, and so they all came down the rope again.

24. SLAYING THE MONSTERS BY FIRE.*

In the beginning of the world there were animals that lived with human beings and were kind and friendly, but there were other animals that were very strong and dangerous. At that time, when the earth was new, the grass was taller than the highest trees are now, and many wild animals prowled through the high grass, and that was the reason why the world was so very dangerous. One time the people met in council to make plans to kill all the dangerous animals in the world, and Morning Star, who was one of the head men in the council, arose and said: "There is only one way to kill these animals and that is to

* Told by Wing.

burn the grass all over the world. I know how large the world is and what a big task we have, but we must do it."

As every one was willing to try Morning Star's plan, he told a man who was present at the council that most of the work would fall to him, but that he would appoint two men to help him carry out the work. The man's name was Fire, and the first man appointed to help Fire was the fastest runner in the world, and his name was Black Snake; the second man was the slowest in the world, and his name was Skunk. Fire took hold of Black Snake's tail and put fire on the end of it, and then took hold of Skunk's hind foot and placed fire between his toes. They both started out at the same time, the one going to the north, the other around to the south, so as to meet somewhere in the west, since they started in the east. While these two were on their way the people decided to make a long rope out of soapweeds that would reach up to the sky. Everybody helped make the rope, and as they worked Pigeon would go up into the blue sky to see how near the fire had approached. After a time the people could see that the sky was getting very dark on account of the smoke from the fire, and so they worked hard and fast to get their rope long enough. Finally they had the rope finished, and they appointed Crow to take it up to the sky. Crow took the rope and flew and flew until he was out of sight, and it was a long time before he returned, but when he came he assured the people that he had the rope firmly fastened to the sky. The fire was approaching rapidly, and so the people began climbing up the rope. After the people had climbed up, all kinds of animals came and began to get hold of the rope, and all the bad animals came, and then the rope began to move upward. After the people were high up they sent a man down the rope as far as the first bad animal. This man's name was Bat, and because he had very sharp teeth he was sent to cut the rope. The animal saw him chewing something and asked him what he was eating. Bat said that his grandmother had parched some corn for him and that he was eating it. He kept on cutting the rope, and finally it broke and let the bad animals fall down. When the animals dropped down to the ground Bat followed them down to see what would become of them. He saw a large animal and heard it call all the other animals to enter his body through his nose, ears, and mouth. These animals went in, and so large was the big animal that it had room inside of it for all the bad animals. After all the others were in, Bat slipped in and began to pull out some hair from the animal's nose. That made the animal sneeze, and he sneezed so hard that he threw all the other animals out through his nose. The animals were scattered every place and burned, for the fire was upon them.

Bat flew up where the people were, but he was scorched a little before he could get there, and that is the reason bats are yellowish in color. After the bad animals had all been burned the people returned to the world again, and ever since the world has been a good place to live upon.

25. HOW THE BUFFALO CEASED TO EAT HUMAN BEINGS.*

When the world was new there were many wild and fierce animals, and the buffalo were among the fiercest, for they ate human beings. In those days the buffalo were many-colored and roamed the plains in great herds, and were so numerous that men could not go out on the plains alone for fear of being caught by them. There was one great man who received power from the Father, and he had the power to go right into the midst of these terrible animals and kill them without being hurt. That man was Buzzard, and he was the only man who possessed such power. All the other people had to live in villages together that they might protect each other and hunt together. One time some men went out in the timber alone to hunt turkey and deer. They wandered far, and when they started home they found that they had to cross a long stretch of lonely prairie. While they were hurrying across the vast stretch of country they saw a black cloud arise in the west and come nearer and nearer, until at last they knew that a great herd of buffalo was sweeping down upon them. They threw the game from their backs, threw away their bows and arrows, and ran as fast as the wind. The buffalo, dangerous as they were, were not good runners, and so the men reached the timber before them and ran into the dense thicket.

After these men succeeded in escaping, the people took courage and ventured farther away from home. One time four men went out to hunt bear. They went into the timber that lay between two mountains and there they found the fresh tracks of a bear. They trailed it all through the timber and over the mountain, and found it at the edge of the timber at the foot of the mountain. The bear ran out to the open plain and the men pursued and killed it. While they were cutting it up to carry home they heard a great noise, like thunder, coming across the plains. They looked and saw that the buffalo were upon them. They tried to escape, but it was too late. The buffalo caught all but one man, who succeeded in gaining the timber and climbing a tall tree. All day the buffalo surrounded the tree and tried to butt it down, but could not. Night came on, then they returned to the plains and the man climbed down and ran to his home. He told all the

* Told by White-Bread.

people how the buffalo had surprised them and had killed his three companions. The people hastened to the place, but found nothing but a few bones scattered about. From that time on the buffalo ate many people, until Coyote came. Then the people left this dangerous country and went into another. They went through the gate to the new country, and Coyote went with them. He was the last to go through the gate, and as he went he shut the gate, so no dangerous animals could enter, and he let through only a few buffalo who had never tasted human flesh and so were not dangerous.

26. THE GIRL WHO HAD POWER TO CALL THE BUFFALO.

A girl who had power to call the buffalo lived with her six brothers. The brothers were stars, and every night they left the girl to travel through the sky. Every morning after they had returned from their nightly journey they put the girl in a swing of lariat rope that hung down from the sky and swung her through the air. As she swung through the air the buffalo saw her and came. The boys killed all that they wanted, and then the rest of the herd went away. In this way the girl called the buffalo for her brothers, and so they always had plenty to eat.

One time Coyote came to visit them, and, finding that they always had meat, he decided to come and live with them. The brothers did not think much of Coyote, but they decided to let him stay. Every morning he watched the boys put their sister in the swing and swing her until the buffalo came. Before the brothers would let Coyote watch them swing her they made him promise that he would never try to do the same while they were gone, because if any one else tried to swing the girl he would swing her too hard and she would swing to the sky and never return. Coyote promised, but one day while all of the brothers were gone he called the girl to come and get into the swing. She refused, but he threatened her and made her obey him. She climbed into the swing and Coyote pushed her. The buffalo did not come, and so he pushed her again and caused her to go higher and higher through the air until she disappeared. Coyote became frightened and called to her to come down, saying that if she did not come he would jump up and pull her down. The girl did not come, and he could not see her.

When the brothers came home they missed their sister and asked Coyote where she was. He said that he did not know, but that he thought some monster had carried her away. The brothers knew that Coyote had lied, and that he had been the cause of her disappearance. They drove Coyote away, telling him that he and his children would always be hungry because he had disobeyed them. Then they held a council among themselves and decided to go to the sky and live there with their sister.

27. THE OLD WOMAN WHO KEPT ALL THE PECANS.*

There lived an old woman who was mother to all the pecan trees. She owned all of the trees and gathered all the nuts herself. When people went to her lodge she would give them a few pecans to eat, but would never allow them to take any away. The people were very fond of pecans and they wanted some for their own use, but the old woman would not let them have any. One time the people were very hungry and the old woman had everything in her lodge filled with pecans, but she would give them only a few when they went to see her and she made them eat them before going away. This made the people angry and they decided that something must be done.

There was in the village an old man who had four little sons who were very troublesome and meddlesome. The people—they were the field Rats—thought that these four little boys would be the right ones to go over to the old woman's house some night to try to steal some of the nuts. They chose the four boys both because they were small and quiet and sly and because they were such a nuisance around the village that they would be no great loss to the people if the old woman killed them. The Rats were willing to go because they were always glad to be meddling. They chose one to slip over and make sure that the old woman was asleep. He went to her lodge and peeped in through a small crack and saw that she was still at work. He waited until she finished her work and went to bed; then when he heard her snore he ran back home to tell his brothers to come. When he went inside his father's lodge he saw a stranger sitting there. The stranger was Coyote. He had come to tell the Rats not to trouble about stealing pecans from the old woman, for he was going over the next day and kill her. Coyote was afraid to trust the Rats. He wanted to go himself, so he could get the most of the pecans. The next morning he went over to see the old woman and acted very friendly. The old woman gave him some pecans and he sat down and ate them all up. Then he asked her for some more, and as she turned around to get them he pulled out his stone knife and struck her on the head. She died, and ever since then the pecan trees have grown everywhere and belong to all of the people.

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* Told by Wing.

28. THE COWARD, THE SON OF THE MOON.*

In the beginning, when the people first came out of the earth, a little boy was taken out with his grandparents, but his mother and father were left behind in the earth. The old people loved the child dearly and cared for him, but because they were old they were poor, and so the boy was often hungry. Sometimes other little boys took him to their lodges and fed him, and then the old people were happy; for they did not mind being hungry themselves, so long as their grandson had something to eat. He grew rapidly and soon became old enough to hunt game; then the old people always had plenty to eat, for he was successful on the hunt. One time, when he came home from a long hunt, he found his grandmother sick, and in a few days she died. The boy grieved for his grandmother, but remained with his grandfather to comfort and provide food for him. One day the grandfather, who was an old man, dropped dead. Then the boy, left all alone, gave up to his grief and spent days and nights in mourning. He wandered far away into the timber to mourn, and in his grief and loneliness he prayed that he might die. While he was praying one evening, just as the sun was going down, he heard some one calling him. He turned and saw a man coming, and when the man came near he opened out his arms to embrace the boy, and said: "I will be your father, and I will look upon you as my own son. One time you wished for me, and now I have come to claim you as my own. I am the Moon, who keeps watch over everything in this world. Go back to your people now and some time I will come for you. In the meantime remember that I will always watch over you and give you power."

The young man went back to his home and wept no more, for he did not feel so lonely and forsaken, now that he had a father. After a time a girl came to his lodge and asked to become his wife. He accepted her and they lived together. One time while they were at dinner he said: "Some one is coming with news for the chief." The person was then several days' journey from the village, and so his wife saw that her husband had great power. One time he was told by a mother to watch her child while she went out to get water. She told him that the child was asleep, and if it woke up to give it a buffalo bone to suck. When the mother was gone he woke the child up and cut its leg off. When the mother returned she saw her child lying dead upon the blankets, and saw the young man sitting beside it playing with its

* Told by Caddo George.

leg. She ran and called the people and they came and killed the young man. Soon after they heard that he was living with another family not far away. The people went to the place where they had buried him and saw that he had come out of the grave. Then they went to the family with whom it was reported he was living, and they found him there alive and looking just the same as before they had killed him.

One time the tribe went on the war-path and fought another tribe. All the men went except this man. The chief asked him why he did not go with the others to fight the enemy and kill a man instead of a little child. Coward, for so the people called him, said that his father had not told him to have trouble with people. The chief asked him who his father was, but he did not answer. He arose, took up a war club, and went out to fight. The enemy shot many arrows at him, but soon they saw that the arrows flew off from him, and they knew that he was wonderful and could not be killed. They turned to run, and as they ran he killed many with his war club. The next day he became sick and began to shake all over. Finally he vomited all the arrow heads that had pierced his body, then he bathed himself and was well. After that the people knew that he had some great power. Many years after he told his people that he was going away, and that evening when the Moon came up he pointed to it and said: "There is my father." Then he arose from the earth and went up to the Moon.

29. THE FIRST WAR PARTY.*

When the people came into the world there were so many that they had to be divided into groups, and each group was given a different name, although they all belonged to the same tribe. After a time the tribes began to fight with each other, and the Caddo fought the Kiowa and Comanche. The Caddo gathered one time in council and the chief told the errand-man to cry out for all the young men to come to the council. The young men came and the chief asked all of those who wanted to fight the other tribes to sit in a circle. After the circle was formed the chief brought the largest buffalo hide that he had and laid it upon the ground in the center of the circle. Then he gave each man a stick and they all beat the buffalo hide with the sticks and sang a war song. They began singing at sunset and continued until Morning Star drove the other stars away.

In the meantime the chief and his assistants went ahead to choose a good place with water near by to make a camp. At dawn all the men

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* Told by Wing.

arose and marched out to the place, continuing their war song as they went. They were not allowed to go back to their homes, but had to march all together out of the village. They waited until noon at the place the chief had chosen, so that others who decided late to join the party would have time to catch up with them. They all stopped their songs and ate, and, while they were eating, the chief made the following speech :

"I want to make certain rules for you, my men, for if you are to become great warriors you must learn to obey. First, I want all to move forward in one body and want none to stop by the way. I will appoint two men who shall be water-carriers, and I want each man to drink only when water is brought by the water-carriers, and not to stop and drink at every spring or stream. A drink of water three times a day is enough for each man. We will also eat three times a day. March on, now, and remember to keep in one body, that we may overcome the enemy."

They marched by day and made camp by night. The chief always camped about a hundred yards in advance of the others, facing the enemy's country. When the men were near the enemy's country the chief appointed four men to go on ahead as spies and to come back at night and report. They went out in all directions, but before going they arranged a meeting place, so that if any one saw the enemy he could go to that place, give the signal, and the other spies could join him and all race back to tell the leader that they had seen the enemy. When they reached camp they stood in line and waited for the water-carriers to give them a drink before they began to speak.

They went on until they found the enemy and fought them, but scalped only one, for that was enough to show that they had been victorious. When the battle was over the warriors were all left to do as they pleased. The chief sent word to their homes that they had defeated the enemy and were bringing back a scalp. The people decked themselves in paint and feathers and went out to meet the returning war party. When the people met the party the chief told the man who had the scalp to put it on a pole, and then all the young men raced for it, and the one who got it ran on until some one overtook him ; then that one took the scalp and ran on until some one overtook him, and so they raced home. The people at home were waiting for them, and when they arrived they all joined in a big war dance.

So it was with the first war party, and so it has been with all war parties since that time.

30. THE POWER OF THE CYCLONE.*

A boy sat down on the banks of the river to rest after his morning bath, and as he sat there watching the sun come up and listening to the water and trees, a voice from some place spoke in his ear and said: "Boy, I have been watching you at your bath every morning. I know that your grandmother has sent you here every day in winter and in summer to plunge into the water, no matter how cold, that you might gain strength and become a strong man, hardened to endure. I have come to give you that strength that you desire, and even more."

The boy looked about him through the trees and in the water, but for a long time he saw nothing. After he had gazed into the water for a long time he saw slowly arising to the surface a man. The boy was not frightened, but sat still on the bank and waited. The man came close and spoke to him, saying: "Dive into the water four times, and as you dive always face the west." After the boy had dived four times and again sat on the bank, the unknown person said: "I am the power of the Cyclone. Once I was so strong and powerful that I held all the Winds in my control, and all people feared me, but now I am growing old and my strength is going from me. For some time I have been looking over the world to find some one to take my place and to whom I could intrust my powers. As I was looking and almost despairing of finding a worthy young man, I found you. From that time I have been watching you, and now at last I am come to give my power to you. Swing your arms about." The young man began to swing his arms, and soon a big, black cloud rolled up in the north. It passed to the west, and then, as the boy threw his arms about faster, the wind broke from the cloud and passed through the forest, tearing up trees by the roots and tossing the waters in fury as it went. At last the man cried in a loud voice that was barely heard above the roar of the winds, "Stand still!"

The boy dropped his arms at his sides and stood breathless and panting with the exertion. The man said: "You have received my power. Take care that you never abuse it, and send the cyclone only in the spring, when it is necessary. I give you the name 'Path-of-the-Cyclone' to be yours, and people shall know you by that name." Then the man disappeared. Years after the people came to know the power the boy possessed when they saw him carried through the air to the sky on the breast of the cyclone.

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*Told by Wing.

31. HOW THE CANNIBAL WAS DESTROYED.*

In the beginning of this world there lived many kinds of fierce animals. Among these animals was one especially that was called by the people living in those times the cannibal.

One time there were three men who went out hunting. They went a long way from home and kept on going farther and farther in search of game. One day they came to a country timbered with many large trees. They came to one of these trees and saw that something had been climbing on the tree, and near the base there was a large hole. The men thought that a bear must have made the hole, and that the bear was in the hole. They gathered dry leaves and grass and made it up into a small bundle, and they set the bundle on fire and tied it to the end of a long pole and thrust the burning bundle into the hole. They kept on dropping bundles into the hole until they thought it about time the bear should come out. One of the bundles which was put into the hole dropped out from the hole, and then they knew that the bear was coming out. Finally some strange animal came and peeped out from the hole, and it was not a bear, but a cannibal.

As soon as they saw and knew what kind of animal it was, they ran. The smoke cleared away and the cannibal came down from the tree and smelled around until he scented the tracks of the men, and then he began to follow them. These men were on foot and the cannibal was very swift, and so it was not long until he overtook one of the men and killed him. Then the animal took the man back to the woods, to the large tree, and went back after the other two men. After running a long way he overtook the second man. He killed him and carried him back and placed him by the side of the first man. Then he returned for the third man. When the third man was almost overtaken, and was running with all his might, he saw something flat on the ground in front of him, but he did not stop. He saw that it was a mountain-lion, lying there watching and waiting for the approaching cannibal. The man ran on a way, then turned around and looked back to see what the mountain-lion would do. The cannibal did not see the mountain-lion lying there, and before he knew anything the mountain-lion jumped upon him and seized him by the throat. Finally the cannibal was overpowered and killed, and then the man started on for his home. When he got home he told his people what had happened to the other two men. When they all heard this they started down where he last saw the cannibal, and when they got to the place they found nothing

* Told by Annie Wilson.

but many white and black wolves, which had already eaten the body, and there was nothing left but the bones of the cannibal. The men went on to the tree where the cannibal had lived. The tree was not burning, and so the men began to cut the tree down, and when it fell they found two bodies. They took the bodies out from the tree and buried them a short distance away.

32. THE YOUNG MEN AND THE CANNIBALS.*

Ten boys lived with their grandmother. One day the oldest went out to hunt and did not return. The grandmother worried about him, and so the next day one of his brothers went to look for him. He did not return, and so the next brother went out to look for his brothers. He did not return and another went, and so on until the ninth boy went out, leaving his little brother at home with his grandmother. They waited long, but none of the brothers returned and no news came of them. They worried and grieved and became sadder each day, until at last the youngest boy declared that he was going to look for his brothers. His grandmother begged him not to go and leave her alone, for she felt that the same evil fate would befall him that had come to his brothers; but the boy was determined and prepared to go. He went out and prayed for help and put an eagle feather in his hair just before starting, thinking that it might have some hidden power. The boy traveled far, and after a time he saw a tipi. He approached the tipi, and as he went near he heard some one laugh and say: "Another one is coming. Cook some corn and we will soon have the meat." The boy understood the meaning of this, but he was so sad and weary that he thought he would as soon die as live, and so he went on to the tipi. An old man came out of the tipi and said to him: "Are you looking for your nine brothers?" "Yes," the boy answered. Then the man said: "I know where your brothers are and I will put you on the right path to find them, but first you must do some work for me. Lift that big log there and put it on the fire. I will give you four trials, and then if you can not do it you must lie down upon the log and let me lift it."

The boy did not believe anything the man said, but thought he would try to lift the log and see if some power would not come to his aid in answer to his prayers. He tried four times, but could not move the log; then he lay down upon it. The old man was just about to spear him with the iron nose of the mask he wore, when some unseen power pulled the boy off the log, and the iron nose of the mask caught

* Told by Wing.

in the log and held the old man fast. A voice said to the boy: "Run to the tipi and take the pounder away from the woman who is pounding corn, bring it here, and beat the old man to death." The boy obeyed, and when the old man was dead, the voice said: "Gather up all of your brothers' bones. I will help you, for I know the bones of each boy, and put them in nine piles." A strange man, the possessor of the voice, appeared and helped the boy gather up the bones. When they had them all piled up the man said: "Put your robe over them, shoot an arrow up in the sky, then cry: 'Look out, brothers, the arrow will hit you!'" The boy obeyed, and as he cried "Look out, brothers, the arrow will hit you!" his brothers jumped out from under the robe. The man then told them to burn the tipi with the man and his wife in it and to scatter the ashes. After they had done all that, the man said: "Return now to your grandmother. I am the Sun and I have helped you destroy the cannibals." Then he disappeared. The brothers all returned to their grandmother, who had almost grieved herself to death. They told their story, and the youngest boy told how the Sun had taken pity on him and helped him; and from that time all the people knew that the Sun was their friend and always willing to help them in times of trouble.

33. COYOTE AND THE SIX BROTHERS.

An old woman lived alone with her seven sons. They were all good hunters and kept her busy preparing the game that they killed. One day the oldest son went out to hunt and did not return. After several days his dogs came back, but he did not come. The second son decided to go to search for his brother, and so he took the dogs and started out. After several days the dogs came back, but the second son did not come. The third son decided to go after his missing brothers. Again the dogs returned alone, and the brothers did not come. The fourth, the fifth, and the sixth sons in turn went to search for their missing brothers, but each time the dogs came back alone. The youngest son wanted to go, but his mother could not give him up, for she feared that he, too, would go, never to return. One day, after the brothers had been gone a long time, the little boy saw a raccoon in a tree. He asked his mother if he could not take his bow and arrow and kill it. She said that he could, and gave him his bow and arrow. He chased the raccoon from one tree to another until it had led him far into the thick timber. Finally it ran down a hollow tree and he climbed the tree to get it out. While he was in the tree he heard some one speak, and, turning around, he saw a little old woman standing by the tree. "Throw the raccoon down here, and I and the dogs will kill it," she said. He threw the raccoon down and the old woman killed it and one of the dogs. Then she said, "There is another raccoon in the tree." He pulled out another raccoon and threw it down. She killed it and another one of his dogs. He saw another raccoon in the tree and he pulled it out, and again she killed it and another dog. He continued to pull raccoons out of the tree until he had pulled six, and each time the old woman killed the raccoon and another dog. As the boy was about to pull the seventh raccoon out, it spoke to him and said: "Boy, when you get me out, throw me just as far as you can. I will run away and the old woman will chase me. While she is chasing me, you must jump and run home as fast as possible. She has already killed all of your dogs, and she will kill you next. She is a witch, and is the one who has killed all of your brothers. You must run from her." The boy said that he would, and then he threw the raccoon just as far as he could. While the old woman was chasing it he jumped out of the tree and started to run home. The old woman killed the raccoon, then returned to the tree, and when she found the boy gone she was angry, and started after him as fast as she could run, but he was too far ahead, and she could not catch him.

When the boy reached home he told his mother all that had happened. That night he had a strange dream, in which he dreamed that he met Coyote, and Coyote told him that his brothers were not dead, but were with some bad people who made them work so hard that they would soon die if they did not get away, and Coyote promised to help him rescue his brothers. The next morning he told his mother his dream, and she told him that his dream would probably come true. That very afternoon the boy went out to hunt, and while he was walking along he met a man, and the man told him the same thing that the man in the dream had told him. The boy returned to his home and the man went on through the timber until he met Flying Squirrel. He was one of the bad people's slaves and had to work for them. Coyote, for he was the man, began to talk to Squirrel and asked him about the bad people. Squirrel told him that the bad people made slaves of all of the people that they could catch alive, and that they ate all that they killed. Coyote asked about the six brothers, and Squirrel told Coyote that they were slaves like himself and could not get away, but had to work. Coyote said that he would like to help them, and that he thought he could, for he was very cunning and had a good deal of power. Squirrel told Coyote if he could only find some way to kill the wicked chief that there would be no more trouble. Coyote said that he thought he could plan to kill him if he could only get to him, but that he lived across the river and had no way of getting across. Flying Squirrel said that he would take him across if he thought he could hold on to his tail as he flew. Coyote said that he could, and so they started. When they were almost to the other bank Coyote let go Squirrel's tail and fell into the water. He hid in the tall grass until he thought of a plan. When he had made up his mind what he was going to do, he turned into a nice, new corn mill, and floated out on the water where he would be in plain sight. Soon a woman came down to the river to get some water. She saw the mill and tried to get it, but could not. She ran back and told the chief about the nice, new mill, and asked him to get it for her. He told her that he was afraid it was Coyote, or some one trying to play a trick on them, but the woman said that it could not be anything but a fine corn mill and that she wanted it. The chief sent some one to get it, and then all of the women came to pound their corn in the new mill. They used it for several days, and all thought it was the best mill they had ever had. One day some one put some fine sweet corn in it, and after she had ground a little while all of her corn was gone. She ran to the chief and told him. He said that the corn mill was Coyote, as he had feared, and he told the people to bring it to him. They brought it, and he placed it on the big log where he always speared people with his long, spiked nose. He raised his head high, then dropped it, and his nose stuck in the log so that he could not get loose. The corn mill had rolled off the log and turned into Coyote. He grabbed the chief by the head and held him there while he called all the slaves to come and kill him. With the others came the six brothers. After they had killed the chief, Coyote told all that they were free, and to go to their homes. The six brothers returned to their home, and ever after that whenever they killed any game they always left some for Coyote.

34. THE DEATH OF THE CANNIBALS.*

There was a village called Tall-Timber-on-Top-of-Hill, and the people decided to move from that village to another. They were all ready to go when a baby was born to a young woman whose husband had died. The woman could not make the long journey with the new baby, and the people were unwilling to wait for her, so they decided to go on and leave her to follow when she was strong enough to carry the child. The woman remained alone in the deserted village for many days. She was afraid to be there alone, and counted the days until she could start to the new village. One night as she sat with only her child in the grass lodge she heard some one outside, and a strange voice begged admission. She was frightened, but let the man in, and said: "Are

*Told by Shorter.

you from my people?" "No," said he, "though I often go around their village at night. Do not be frightened and I will tell you who I am. People call me Spotted-Wolf. I have come here to see you and your child and to beg you not to start too soon on your journey, for there are many dangerous animals on the way." The woman replied: "I know, but I want to go to my people. It is lonely here, and I am afraid." Spotted-Wolf said: "I am afraid something will happen to you if you go now. Take this tobacco, and if you meet danger and need help throw some of it to the four directions and call to me, and I will come and help you." The woman took the tobacco; then Spotted-Wolf arose and went to his home.

After a few days the woman decided to start on her journey. She put her child on her back and started. After she had traveled three days she saw in her way a strange-looking being. She went on, and as she came nearer she was not certain whether it was a wild animal or a person; but in a moment it dropped on the ground and rolled over twice, and then she saw that it was a wild animal. Again she looked and saw that it had taken the form of a person. Then she knew that it was a cannibal, for these creatures first appear as human beings; then they turn into wild animals and eat people. She was frightened so that she could not go on, for she thought that she and her child would be eaten by the cannibal. She thought of Spotted-Wolf and took some tobacco out of her bag and threw it to the south, the east, the west, and the north; and as she threw it she prayed that Spotted-Wolf would come and help her. Soon she heard the howl of a wolf in the south, then another in the east, another in the west, and another in the north. The cannibal stopped growling at her and looked frightened. In a moment big spotted wolves were coming from the four directions. They killed the cannibal, and the wolf from the south conducted the woman and her child in safety to the village of her people.

There is another kind of cannibal, though not so dangerous as the one who first appears as a human being, then turns to an animal. These cannibals live as human beings and eat people only after they are dead. Whenever they hear of any one who is sick and about to die they pretend to be sick, too, and when they hear that the sick person is dead, they pretend to die, too, and are buried; but in the night they jump out of their graves and steal the dead person before the spirits can take him away.

One time there was an old medicine-man and he had noticed how certain people got sick whenever they heard of any one else being sick, and how they died when the sick person died, and then how they always came to life again. He watched one of these beings for a long time;

then he pretended to be very sick and caused it to be rumored about that he was about to die. Soon he heard that the person he had been watching was sick. Then the medicine-man pretended that he was dead, but before he pretended to die he told his sons to put a bow and some arrows in his grave, and told them not to put much earth over him when they buried him. As soon as the person heard that the medicine-man was dead, he pretended to die also, and was buried. That night he jumped out of his grave and went to get the medicine-man. The medicine-man heard him coming, and so he jumped out of his grave and shot an arrow through the cannibal and killed him, so that he never came back to life again. Then the medicine-man told the people what he had done, and ever since that bows and arrows are always put in the graves with the dead, that they may shoot the cannibal.

35. THE MAN WHO MADE ARROWS FOR GHOST.*

Two men arose and went out to hunt before daybreak, and they were a long way from their village when the sun came up. They hunted all day and far into the evening, but did not find anything. They decided to stay in the timber and sleep that night, so they might hunt next day, for they hated to go home empty-handed. They threw themselves down on a soft, grassy place and slept soundly, for they were weary. After they had been asleep for a long time both awoke with a start and listened. Soon they heard a voice whooping, the same that had awakened them. One of the men was so frightened that he jumped up and ran for home through the dark. The other man was brave and was ashamed to run, for he had not run from anything in all his life. He arose and stood his ground. Soon a dead person stood before him. He asked the man if he could help him get into Spirit Land. He said: "I have been trying for a long time, but can not get any farther, for my bowstring has a knot in it. Can't you give me a bowstring and make me two new arrows?" The man said that he would, and so he sat down to make the arrows. Then he put a new string on the dead person's bow. The dead person shot the arrows and went up in the air with them. Before going he told the man that he would whoop when he was high up in the air, to let him know that the arrows had carried him up all right, and he wanted the man to whoop back, to let him know that he had heard him. The man listened and soon he heard a whoop. He answered it, and then he heard nothing more, so he knew that the man had entered Spirit Land. The next day he returned to his people and told them the story, and ever since that time bows

* Told by Wing.

and arrows are always made and buried with the dead, so that they can go to Spirit Land at once and not have to wander about. But no one ever makes bows and arrows at night, because they are afraid some of the ghosts might come for them and cause a death in the family, for whenever a ghost appears it is a sign of death.

36. THE LAZY BOYS WHO BECAME THE PLEIADES.*

Long, long ago, in the beginning of this world, there lived an old woman with seven children, who were all boys. The boys were full of life and fun and they would go away from the others and play all the day long, and would not work, nor take time to eat but twice a day—morning and evening. When they came home in the evening their mother would scold them, and one evening when they came home late for their supper their mother would not let them have anything to eat. The boys were very angry and went back to their play and determined on the morrow to go away where they would never trouble her any more. The next morning early they went down to their playground before breakfast and began to go round and round the house, praying to the spirits to help them. At last their mother noticed and heard what they were saying, and as she watched them she noticed that their feet were off the earth, and then she knew that something was wrong, and she ran out trying to get her children, but it was too late. With every round they rose higher and higher in the air, and were soon above the roof of the house. They circled higher and higher until they went up to the sky, where we can see them now as the Seven Stars. These seven boys who were taken to the sky were very indolent, and when the work time came they would always slip off and play. That is the reason that during the winter months the Seven Stars can be seen; but at the beginning of the spring months, at the work time, the Seven Stars are gone.

37. THE LOST TIMBER SPIRITS.†

When the world was new the old man, Coyote, decided that if a man, woman, or child died they should return to the earth again after ten days. Finally Coyote made another rule, and that was that when anybody died and was buried within six days he should stay under the ground, but if not buried by the seventh day he might escape. If caught before he succeeded in getting away he was to be brought back home. When the person was caught, a fire was kindled all around him; but finally he threw off the fire from him, and then was taken back to his home,

*Told by Wing. †Told by Short-Man.

where he was kept for six days and nights. At the end of the sixth day some old woman washed him, and then they let him go, and he became a real person again.

When a person dies they dig a hole in the ground about four or five feet long and about three or four feet wide—according to the size of the person—and the body is laid head toward the west and feet toward the east. One of the family builds a fire at the feet of the person, and this fire should be kept up for six days and nights. Very often the person forgets to keep up the fire and lets it go out before the end of the sixth day, and when this happens they find that the grave is open and tracks are seen leading toward the east. They follow the tracks sometimes and overtake the dead person, but generally he gets away from them when they do overtake him. They build the fire all around the dead person; the wood for that purpose is cedar and mulberry trees, and the sparks from the fire get on the person. At first the dead person pays no attention, but the people keep on building up the fire until the dead person begins to look around and tries to escape the sparks from the fire. Then they know the dead person is coming to life again, for he is beginning to feel, and then they take hold of him and bring him back home, where he is kept for six days and nights. At the sixth day, in the early evening, some one of the family would bathe him, and then he would live again. When the dead person is not caught he becomes something like a very large monkey, and lives in the thickets and timber. Whenever the people meet a dead person he talks to them, and so the people think that dead people are crazy people. They do not know where their homes are or who their relatives are, and so they go off and stay in the woods or among the wild animals. That is the reason that large monkeys are called "the last people in the thickets." When any one or two people go out to hunt in the thickets or woods they always meet these monkeys, and monkeys always ask for a wrestling match. They are very strong little men, and if the people do not pay any attention to them, they bother them all night long. These creatures are still living, but they do not talk as they did when the world was new.

38. THE MAN WHO TURNED INTO A SNAKE.*

One time two boys who were close friends went out hunting. They met a large snake, and one of the boys killed it and cooked it. The other boy begged him not to eat it, but to eat the buffalo meat that he had prepared; but the boy would not listen to him and ate the snake meat. That was in the evening. The next morning the boy who had

*Told by Wing.

eaten the snake meat began to turn into a snake. After another day and night he had completely turned into a snake. He told his friend to go to the mountain and find a hole for him to live in. The friend found a hole and carried the snake to it. The snake told him to go to their village and tell his people what had happened to him, and to tell them that whenever they went to hunt to stop and offer presents to him and he would help them in the hunt. The snake lived there for many years, until the lightning killed him.

39. THE WOMAN WHO TURNED INTO A SNAKE.*

A long time ago there lived a man and his wife and a dog. At that time the animals talked like human beings, and so the dog talked to the man and woman. Every day the man went out to hunt, and as soon as he was gone his wife always went away and never returned until evening, just before her husband came. He did not know that she left home in his absence until one time his dog said: "I believe you ought to know that your wife goes away and stays all the time that you are gone." The man told his dog to follow her the next time she went away. Early the next morning the man started out hunting and the woman left home as usual. The dog followed her, but stayed a good distance behind, so that she did not know that he had followed her. She went to the large timber and stopped at one of the large trees and stood there looking up, and then after she had stood there for some time she whistled once, and then again and again. The third time she whistled the dog saw something moving out from a large hole in the tree, and finally the dog saw that it was a big snake. The snake came down to the ground and went straight to the woman, and began crawling up on her and coiling round and round her body. Finally the snake began to move away from her and crept back to the hole in the tree. That night the dog told the man what he had seen. The next day the man made many arrows and told his wife that he and the dog were going out fishing. Instead of going down to fish they went to the place where the snake was, and when they were there the man went near to the tree and whistled three times. The snake began to creep out, and when it had reached the ground the man shot it and killed it, and then cut it up in very small pieces, so that the pieces looked like pieces of fish. They went down to the river and began to fish, and they caught a few small fish and took them home. When they arrived at their home the man told his wife that he was going to cook the fish himself, and told her to go in the grass house until the dinner was brought to her. She went,

*Told by Annie Wilson.

and the man began to cook the fish and the snake flesh. When he was through he took the snake flesh to his wife for her dinner. He and the dog ate the fish. He sent the dog into the grass house to see what his wife was doing, and the dog saw that she was eating the snake. He was sent in the second time, and he saw that she was scratching herself all over her body. Every place she scratched herself the skin would turn the color of the snake skin, until she finally turned into a snake. She crept away from the grass lodge and went to find the snake, for she did not know that he was dead. Some time after, the man went out hunting and he came to a large tree. He heard something making a noise inside of the tree and finally saw a large snake come out from the tree. He knew that it was his wife, but he passed on.

40. HOW OWL FOOLED THE GIRLS WHO WANTED TO MARRY THE CHIEF.*

One time there lived an old man and woman who had two beautiful twin daughters. These girls heard of a chief who lived in another village, and rumors of his great wealth and his fame as a great chief had traveled far. The girls asked their parents if they might not go to the chief and offer themselves in marriage. Their parents consented, and so the girls started to the chief's village. They did not know just where the village was, but they started in the direction that they thought it was, and decided to ask the first person they met to direct them. They traveled along for a time and then met a man with a turkey in his hand coming down the road. They stopped him and began to talk to him. "We want to marry this famous chief, for we hear that he is good and very wealthy, but we do not know him. We have never seen him, we have not even been to his village, and perhaps we would not know him if we should see him." The man grinned to himself and said: "I am the chief and I live just a little way from here; I have been away attending a council. Well, I must say that I am willing, but wait here while I run on home and tell my grandmother."

The girls waited. They thought it strange that so great a chief should have to tell his grandmother, but they said nothing. The man, who was no other than Owl, ran on to his home, and calling his grandmother, said: "Clean up the lodge and put it in order. I am going to bring home two girls whom I am playing a joke on. They think I am the rich chief and want to marry me." After they had cleaned the lodge, for it was very disorderly, Owl said: "I am going to put this turkey which I have brought home over my bed; when you get up in the morning ask me which turkey you shall cook and pretend to point

*Told by Wing.

to one, and I will say, 'No, take this.' Then the girls will think that we have many turkeys and many good things to eat."

Owl went back for the girls and brought them to his grandmother's lodge. They were pleased, for everything looked neat and nice, and so they married Owl. Every day Owl came in with a turkey, and he always pretended to have been out hunting. Really he had been at the council, and the chief gave him the turkey for allowing him to sit on his back. At all the councils the chief always sat on Owl's back, and so he gave Owl a turkey every time to repay him for his trouble and the pain of holding him so long. After many moons the twins grew weary of nothing but turkey and they began to suspect something, so one day they followed Owl when he went away. They followed and saw him go to a large grass lodge. They peeped through an opening, and there they saw Owl sitting in the middle of the lodge with the chief sitting on his head. They gave a scream. Owl recognized their voices and jumped up, throwing the chief off his head, and ran home. He gave his grandmother a terrible scolding for letting the girls follow him and find him out. The girls felt so ashamed when they discovered how they had been fooled, that they slipped off to their home and told their father and mother their experience.

Owl sat in his lonely lodge and thought for a long time about the twin sisters, and the longer he thought the more angry he became, because he had been fooled at his own joke. Finally, he said to his grandmother: "We must kill the people, and in order to do that we must gather all the water, from the smallest to the largest rivers and the springs and the lakes. We will have to dig a big hole here, and when we finish the hole we will begin to dam the waters out from all the rivers, springs, and lakes." They worked long and hard, and the people did not notice that the creeks, lakes, and springs were getting low until they were dry.

The water was gone and the people were dying of thirst, while Owl splashed and swam about in the water in the big hole where he had all the waters of the earth. Every one went out to search for water, and Crow, who was snow white then, went with the others. He came to a field where the grass was all dried and withered for want of water, and big grasshoppers were jumping about in the grass. Crow ran after them and made such a loud noise in trying to catch them that all the people heard. They thought that he had found water, and so they ran in great haste. When they found that Crow had not found water they were all disappointed and angry at him for fooling them. Coyote jumped on Crow and rolled him about in the black earth until he was black, and ever since that time the crow has always been black as night. After that

Coyote made a rule that if any one made a loud noise and aroused the people's expectations he must either lead them to water or take a hard whipping. Turtle was traveling along one day searching for water, as they all were. He went down to the river bed, where the water had been, and he fell into a large crack in the dried mud. He began to halloo for help. The people heard him and all ran down to the river bed, for they thought surely he had found water; but when they found he was only calling for help, Coyote took him out of the crack and gave him a hard whipping. He whipped him so hard that he cracked his shell, and to this day turtles bear the markings of the cracks on their shells.

One time some one was going along looking for water, when he heard a big splashing noise, and he knew that it was the sound of water. He went until he came to the hole where Owl sat playing in the water. He went back and told the people. They gathered in council to decide how they could get the water from Owl. They were about to give up when Flea said that he would go to Owl's lodge and try to free the water. He went, and as he entered the lodge Owl's grandmother was about to take a bath. She had a big jar full of water sitting in front of her. Flea slipped up to her, crawled up her leg, and bit her; she gave a big kick and upset the jar. When Owl saw the water running in every direction he opened his eyes wide in astonishment, and they have always looked that way ever since. All the people felt very grateful to Flea, and Coyote put him on his back that he might have a good warm home.

41. THE POOR HUNTER AND THE ALLIGATOR POWER.*

One time the hunters went out on a two months' hunt. They took their wives with them. After they had gone a long distance from home they camped. Among these hunters was a poor man and his wife who were hungry and starving, while every one else was killing plenty of game and having an abundance to eat. The poor man would go out to hunt from early in the morning till sundown and come home with nothing to eat. He continued to hunt day after day, expecting to find deer or some game, but always returned without anything. The people would not give him anything to eat and would make fun of the unfortunate man because he could not kill anything. One morning he arose early and started out and hunted all morning. About noon he heard some one calling him, and the person was a long distance away. He started to see who it was and what was the matter with

* Told by White-Bread.

him, and when he got there he asked the person why he called. "Well," said the person, "I want to find out where there is water." The hunter told him there was some water a short distance from where they were. He did not know who the man was, for there was no such person among his people. The unknown person asked the man to carry him to the water, so the hunter told him to get on his back and he would carry him. When they reached the water the unknown man told the hunter to take off his clothes, and so he did, and then the unknown man told him to get on his back, saying: "It is now my time to carry you on my back. Shut your eyes and do not open them until I say so." The man obeyed, and when the unknown person told him to open his eyes he did not know where he was. Then the unknown person told him that he wanted him to come and see what he had. The hunter looked and saw the heads of all kinds of animals. "Now," said the unknown person, "there is what I have killed, and I will tell you why I brought you here. I am going to give you some of my powers that you may kill game as I do. Point out the heads of the animals that you want to kill." The man pointed to the largest deer head, bear head, etc. "And now," said the unknown person, "you must not tell any one how and where you obtained your powers. All people call me Alligator, and I will give you these powers as long as you are able to hunt." Alligator then told him to shut his eyes, and when he told him to open them he saw that he was upon dry land once more. Alligator told him to go hunting, and so after he put on his clothes he started out to hunt.

He did not go very far until he saw four big deer coming toward him and he killed every one of them. He dressed them carefully and then left them while he went to his camp. When he reached his camp he found his wife there, but nothing to eat. He went out and led up two of his horses and asked his wife to go with him. They arrived at the place and found the four deer. The man put two of the deer on one horse's back and two on the other one, and they started back to their camp. As they came into camp with their horses loaded with meat, everybody at the camp saw them and wondered, for they did not think the man could ever kill a deer. After that time he never failed to bring back much meat when out hunting. When the people started back to their homes they discovered that this man, whom the people had always made fun of, had been the most successful of all the hunters. He had killed the most deer, and besides he had killed the largest deer that was ever seen by the people, and he had killed the most bears and the most of every other kind of game.

The people named him Deer-Head, because of his braveness in killing big deer. Deer-Head lived with the people many years and was well known among his tribe, but one time he disappeared. It was but a short time until the people noticed that he was missing, and they wondered what had become of him.

Deer-Head had only one younger brother, and when the people would go and ask Deer-Head's wife where he was she could not tell, for she did not know where he was or what had become of him. Finally one of the men went where Deer-Head's little brother was, and he asked him if he knew where his big, brave brother was, and he replied that his brother had gone home; that some one came after him during the night and had taken him away that same night. Then they asked him if he knew which direction they took, and he said that he did not know where he went, but that he said he was going home.

While out hunting a long time after this one of the men found a large deer and the deer did not try to get away from him. When he came near he shot the deer, but the deer kept on walking very slowly and the man followed until the deer finally went over the hill where the man could not see him, and then he heard some one calling him to come on, and it was the deer that was talking. The man did not keep on, but turned and started back home. When he got home he told the whole story of the deer, and then the people thought the story of the deer was true, and that Deer-Head had changed into a deer.

42. THE BOY WHO MARRIED A MOUNTAIN-LION.*

A little boy often told his parents that he was a red mountain-lion. No one believed him, but they called him Red-Mountain-Lion. When he grew to manhood he was a successful and famous hunter. He went off alone for days at a time and always brought back much game. One time it was noticed that he acted queerly when he returned from the hunt, and so the next time he went his brother followed him. He tracked him through the timber up the rocky side of a mountain. He heard voices among the rocks, but could not see any one. He climbed on until he saw just above him a cave in the side of a steep wall. He looked in and saw his brother in there with a female mountain-lion. He went home and told what he had seen. After a few days Red-Mountain-Lion came home and acted stranger than ever. One time he heard some men talking about going to the cave and killing a mountain-lion that some of them had seen there. The man started out at once and alone to hunt, and he went straight toward the cave.

*Told by Wing.

The men started out to hunt the next day, and when they came to the cave they saw the foot-prints of a man and a mountain-lion leading away from it. They tracked them down the mountain and up another, and then they gave up and returned to their homes. The man did not return to his people, but many years afterward he was captured by a hunting party and carried to his home. He decided to stay at his home then. One autumn he and his brother decided to form a war party. The brother was to be the leader, and so he went off to get some power before starting. He wandered about alone until he found a rattlesnake skin and a red mountain-lion's tail. He took them and then prayed to the rattlesnake and red mountain-lion for their powers. Then he returned home and hid the skin and mountain-lion tail, for he did not want his brother to know what he had. For some reason or another the war expedition was given up. Then the man should have thrown away the skin and tail, for the animals always want their gifts returned if they are not used for the purpose they have given them. If they are not used or returned something always happens to the man who has received them or to some member of his family.

A long time after the war party had been given up Red-Mountain-Lion awoke one morning and heard a turkey cackling. He slipped out to catch the turkey, and while he was slipping upon the turkey he heard a rattlesnake by the side of him. He moved away and heard another. Again he jumped aside and heard still another.

The woman prepared the morning meal and waited a long time for Red-Mountain-Lion to return; then his brother was sent to look for him. His brother found him unconscious and called some men to help carry him to the lodge. Red-Mountain-Lion was scalped, but the only tracks that could be found were those of a mountain-lion, and they were only around his head, and did not come from or lead to any place. They sent for the medicine-man. He came and after he had examined Red-Mountain-Lion he asked his brother if he had not planned a war expedition and prayed for power and received gifts from the animals. The brother admitted that he had. The medicine-man told him to return the gifts to the woods where he had found them, and told him that his brother should have known better than to have kept them. The man obeyed, and then they took Red-Mountain-Lion to the creek and bathed him, and he recovered, but he was always foolish. He lived to be an old man, but some one had to kill him in his old age, because he became more foolish and did many evil things.

43. BUFFALO WOMAN.*

In a village there lived a cannibal at that time and the people called him Snow-Bird-with-White-Wings. He had a handsome son, who would not marry any of his own tribe. The father named his son Braveness because he was very brave in hunting. Whenever he went out to hunt he brought home many kinds of game that he had killed. Many of the young girls tried to win him as a husband, but Braveness would pay no attention to any of them. One night he decided to go hunting the next day. Early the next morning he started out toward the west. While he was going along looking and watching for wild animals he saw some one sitting ahead of him under a small elm tree. He approached the person and saw that it was a woman. She called him to come where she was, and he obeyed and saw that she was very beautiful and very young. She told him that she knew he was coming there and so she had come to meet him. He listened eagerly to hear what she had to say. She asked him if she could stay with him, and if he would take her to his home and let her become his wife. He told her that he would take her to his home, but that she must ask his parents if she could stay with him. They started for his home at once, and when they arrived the girl asked the old people to let her become the young man's wife, and they consented. After that the young man had some one to love and they lived happily for a long time; but one time while they were alone she asked him if he would do whatever she said, and he finally said that he would. She asked him to go with her to her home and told him that they would return again some day.

A few days after, they started to her home and she led the way. After they had gone a long way they came to high hills, and all at once she stopped and turned around and looked at her husband and said: "You have promised me that you will do anything that I say." "Yes," said he. "Well," said she, "my home is on the other side of this large hill which is before us. I will tell you when we get to my mother. I know there will be many people coming there to see who you are, and they will bother you and try to get you angry, but do not get angry at any of them. The young men will try to kill you in some way. Listen to what I am about to tell you. I was just like you when I met you. I knew you, but you did not know me. I was the one who made you come there to find me. I have said that some of the young men will try to get you angry, and when they get you angry at them one of them will jump on you, and when they see that you are going to try to

*Told by White-Bread.

fight they will all get after you and will not let you go until they have killed you. They are jealous of you. The reason is that I have refused many of them when they have asked me. I have told you what to do when we get there, and now I want you to lay down on the ground and roll over twice." The man did, and when he arose he had changed into a Buffalo. The woman sat there watching him for a moment; then she did the same thing and became a Buffalo. They started on climbing the high hill, and when they reached the top of the hill the Buffalo man looked down toward the west. He saw thousands and thousands of Buffalo. Then the woman told him that they were her people. When the herd saw these two coming they began to move to one certain place, as though to wait there and see who was coming. The woman kept on leading Braveness. He followed her until she came to an old Buffalo cow and then they stopped, and Braveness knew that she was the mother of his beautiful wife. They stayed there for a long time. Every now and then four or five of the young Buffalo would come around and bother Braveness, and so they decided to go back again to Braveness' home. On the way they stopped at the place where they had turned themselves into Buffalo. The Buffalo woman told him to do the same thing that he had done before, and so he rolled over twice and became as he was before, and then she did the same. While they were going she told him not to mention the transformation or her people to any one. When they reached home his father, Snow-Bird-with-White-Wings, asked him where he had been, and he told his father that he had been hunting and then had gone down to his wife's home, and his father did not ask him any more questions.

They stayed at home about one year, and then they made up their minds to go again and see the woman's mother. After they had been living with the Buffalo a long time his wife told him that the old people were talking about killing him; that they were going to have a foot race and that they intended that he should run in this foot race. When he heard all this he was worried and did not know what to do. That night he could not sleep, and he went out to take a long walk. He went a long way and walked very slowly. He heard some one calling, but could not see the person, for it was a very dark night. The unknown person said to him: "You are very young, but you must remember you can not beat those Buffalo running without my help, and I know what they are going to do with you when the race is over. If they beat you running they are going to kill you, and so I am going to help you to win. If I do it there are others who will also help you. If you win the race they will let you have this woman all to yourself and will not bother you any more." Then the unknown person told Braveness to hold out his hand, and when he did this the unknown person placed a small medicine root in it and said: "At the start you will leave them a long way behind, but finally some one of them will catch up with you, but he will not stay with you long. Remember, whenever he comes up with you, to throw this medicine down behind you and you will leave him again a long way behind. Then some one else will catch up with you again, and here is another medicine to throw behind you when the second man overtakes you. This medicine is mud, and you must throw it down when they come too close to you. Soon after you have thrown the mud you will be near the stopping place; there I will meet you."

The next day was the day of the race. At about sunrise Braveness saw the Buffalo coming in from all directions to see the race. While he stood watching them, an old Buffalo came and told him that the young Buffalo would like to have him run in a foot race with them. He went with the old man to the place where the runners started. When the young Buffalo saw him coming they all made fun of him. When he joined them they lined up for the race. Braveness placed himself in their midst and they started. Braveness left the Buffalo a long way behind at the start, and they had to run long and hard before they could come near him. When he saw them gaining on him he threw the root behind him that the unknown person had given him. He was almost winded and thought he could not run any more, when he saw that he was far ahead of all of them again. The next time it took them longer to come up to him, but finally he gave out, and then one of the Buffalo began to gain on him. When the Buffalo was about to catch up, Braveness threw the mud, his last medicine, down behind him and soon he was far ahead again. He knew that he had used all of his medicine, and he knew not what would happen to him next, but he kept on running. When he was nearing the goal, he could hear the others coming close behind him, for some of them were gaining on him and he was giving out. He did not know what to do, but just as one of the Buffalo was about to catch up with him, a heavy wind came up and greatly assisted and kept the Buffalo far behind him until he crossed the goal and won the race. Because wind had helped him at the last moment, he knew that it was wind that had talked to him and had given him the medicine and thus saved his life. After the race he stayed with the Buffalo people for a long time and no one ever molested him again.

Finally he and his wife went back to live with his people. They had one child, and when it was about one year old they decided to go again to see the wife's people, so that her parents might see their grandson. They went and remained with the Buffalo three years, and then they returned to Braveness' home. The child's mother would not let him go out and play with the other boys, for she was afraid he might do things that he ought not to do; but one time, while she was cooking dinner, the boy slipped away from her and went down where the other boys were playing. When he joined them they began to play that they were Buffalo. The little boy began to play with them. He laid down to roll like a Buffalo, and when he rolled over twice he got up a real Buffalo calf, and the boys began to run from him. Just at this time his mother had missed him and she looked down where the boys were playing. She saw them running and thought something must be wrong. She went to see what the trouble was and there she found her son changed into a Buffalo calf. She took him and ran down the hill, and then she dropped down on the hill and became a Buffalo, and then ran away before her husband came back from hunting. When he came back he could not find his wife or his son, and then some one told him what had happened while he was gone. At first he could not believe what he heard, but soon he went down to the place where they had rolled and saw their tracks, and then he believed the story. He never heard of them again.

44. THE GIRL WHO MARRIED WILD-CAT.*

A father and mother had three sons and a daughter. The girl was very beautiful, but very proud, and refused the attentions of the many young men who came to court her. One time a handsome youth came to their home and ate with them and talked to her father and brothers, but paid no attention to her. After he had spent the evening he arose and went home. The girl thought she had never seen so handsome a young man, and she wondered why he had not sought her as all the others had. She went to bed and thought of him for a long time; then she fell asleep and dreamed of him. She dreamed that she saw him coming to her, and finally she awoke and lay still for a long time listening and waiting to see if her dreams were true. She heard a faint noise, and she closed her eyes and prayed that her dream would come true. When she opened her eyes the young man was bending over her, begging her to go with him. She arose and followed him out into the darkness.

When they were a long way from home the man told her that he was not a real person, but an animal, the Wild-Cat, and he told her that if she wanted to go home he would take her back. She refused to go back, saying that she wanted to go with him, no matter what he was. Then he told her that her three brothers were already on their

* Told by Wing.

trail, and that they were very angry with him for taking her off. They hurried on until they came to the mountains. They climbed a high mountain, and then Wild-Cat told the girl to wait there for him. He went away and disappeared among the trees and rocks, but soon returned with another large Wild-Cat, who he said was his grandfather. While the three sat down to rest and talk they heard voices, and the girl knew that they were her brothers' voices. They arose and ran deep into the forest, but still they could hear the voices from the three brothers, who were gaining on them. At last they caught up with them and were very angry. They were going to fight the Wild-Cats, who, of course, were dressed like men, so the brothers did not know that they were Wild-Cats. The sister cried and promised her brothers that she would soon return to her home if they would go and leave them. The brothers at last yielded to her requests and went back home and told her father and mother all that had happened. The father became very angry and swore that he would find his daughter and kill her or the man. He went to the mountains and wandered about in search of her for many days, without food or drink or sleep, until he died.

45. THE WOMAN WHO TRIED TO KILL HER SON.*

At the beginning of this world the people and animals could understand each other and visited each other. There lived in those times a man and wife and one child, a boy about seven years of age. The people called the man Hunter, because he was very fond of hunting and hunted from morning until evening. While he was out, his wife, who was a very cross woman, abused her own boy, as she always did, because she disliked him. She told the boy to stay at home while she went away for a short time. She went out and was gone for a long time. Finally she came back and told the boy to go along with her. While she was gone she had been working hard digging a deep hole in the ground, and when she went after the boy she took him to the hole and threw him in. The hole was so deep that it was impossible for the boy to get out. She put some brush over it to keep any one from finding him. When Hunter returned home he asked his wife where his son was, and she told him she did not know where he was; that she had been looking for him all day long. Then they both went out to look for the boy, but she would not take the man near the place where the hole was, and so they did not find him. They looked until night, and again the next day and the next.

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* Told by Annie Wilson.

In the meantime the boy was growing very hungry, and so he began to cry. Finally he heard some one making a noise at the edge of the hole, but he could not see who it was, and so kept quiet, for he was afraid. Some one spoke to him, saying: "Boy, you are weary and hungry and I have come down to help you out of this hole. Now, do not be afraid of me, but catch hold of my tail and climb up." The boy obeyed, and when he came out of the hole he found that the person was Coyote. Coyote asked the boy if he would go along with him, and the boy said that he would, and so they went on to Coyote's home. He was kept there for three or four years and was kindly treated and was happy. One day he asked Coyote to let him go home and see his father. He said: "I do not want to see my mother; I am very angry at her, and I am going to try to kill her, but I want to see my father, for he loved me and was kind to me. I am going to tell my father how my mother treated me, and then he will help me kill her. I will take my father and mother on a buffalo hunt when I get home, and toward evening we will kill a buffalo. I want you and your children to come near and howl, and then I will tell my mother to come with me to give you some meat. When we go among you I will push her over, and then I want you and your children to jump upon her and kill her."

Coyote consented, and so the boy went to his home. He arrived one evening and his father was very glad to see him. He asked his father if they could go out buffalo hunting on the next day, and he told his father all about what he was going to do with his mother. The next day they went out buffalo hunting, and he and his father found a herd of buffalo and killed one that evening. They made a camp near by, and while the woman was cooking their supper they heard the Coyotes howling. After they had eaten their supper the boy told his mother to get some meat and come with him to feed the Coyotes. He told her to carry the meat on her back. She put the meat on her back, and then they started out toward the Coyotes, and the boy walked behind his mother. The woman was afraid, for it was almost dark, but the boy told her not to be frightened, for there was no danger ahead of them and that nothing would hurt her. They kept on going until they came to the Coyotes. The boy told his mother not to be afraid, but to go among them and give them the meat. As she took another step forward the boy pushed her down, and then the Coyotes jumped upon her. The boy came back to his father and told him all that had happened. The father and son lived together for many years.

46. THE JEALOUS HUSBAND.*

One time the people decided to go on the war-path, and when they were about to start they selected one man to be their leader. They started out and they had to go a long way before they could find the enemy. After they had traveled several days, the head man selected from eight to twelve men to go ahead and spy and see if they could locate the enemy. When any of these men located any of the enemy they would go back and tell what they had seen, and then all the others would ride out to fight the enemy. The leader chose for spies two men who were very close friends and who would always go together from place to place. One of these two was married and the other was single. One day they went out for some distance, and after they had gone about two miles, climbing up and down the hills, they came to a high hill, almost like a mountain. They decided to climb up this mountain so they could look far out over the country. They found on top a big hole in the rock that looked like an old well, and when they looked down into the hole they saw water. The married man told his friend to go down in the hole to get some water, for they were very thirsty. They had a long buffalo-hide rope and on this he descended. When he got to the bottom, he cried out to his friend to pull him up. Instead of pulling him up he threw the rope down the hole and went away and left him. He started for the camp, and when he reached there he told the head man that some of the enemy pursued them and that his friend was killed. It was a custom for the war party to continue the journey until they met the enemy in open battle, but if anything happened to a member of the party, or if any member should die through sickness or be killed, otherwise than in open fight with the enemy, then the expedition was given up and the entire party returned home. When the man told the head man that his friend had been killed, the camp broke up and all prepared to start home. When they returned to their homes, the errand-man was sent by the chief to all the camps to call the people together. When the people came the chief told them what had happened.

The man in the hole was starving, for he had been in there several days without food. Whenever any birds passed over him he would ask for help and pray them to take him out of the hole, but the birds did not seem to take any notice of him. One day, after he had been in the hole nine days, there was a certain kind of bird passed over the hole and the man asked it for help. The bird went on, but finally flew

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* Told by Wing.

over the hole, and the man again asked for help. The bird passed over again, and yet again, but the fourth time it lit on the ground and came near to the edge of the hole and peeped over the rim and saw the man. This bird was Buzzard, and Buzzard told the man not to be worried, that he would help him out, but that he must wait until he went back home after some of his medicine which he required. Buzzard went away, but came back and flew down to the bottom of the hole. Then Buzzard spoke to the man, saying that he was going to take him to the home of the Buzzards until he was able to walk home. The man was told to shut his eyes and then take one step forward. When he did this he stepped on Buzzard's back. Then Buzzard began to fly upward and out of the hole. Then Buzzard told him to open his eyes, and he did so and saw that he was on land again. The man was not able to walk at all, and so Buzzard told him to shut his eyes again, and they began to fly away from the place. After a while the man tried to open his eyes a very little, but Buzzard knew what he was doing and told him not to do it again. In a short time they arrived at the home of Buzzard, and while he was there the young man was treated kindly. After he had been there several days Buzzard asked him if he would like to see his people, and the man told him that he would, and then Buzzard called the man over to where he was, and when he got there Buzzard opened a very small place which was near where he was sitting. The man looked down below him and could see many Buzzard people. Two days after this the man was able to walk around and to do anything, and then Buzzard told him that he was going to take him to his home to see his people once more. Then Buzzard told the young man that his friend was jealous of him, and that the reason he had maltreated him was that he had been told he was going to take his wife away from him. Buzzard said: "I am going to take you home, and we will reach your home about dark, and when we reach a place that is near to your home I will have to let you off. Then you will hear your friend singing in his lodge, which is near to yours. When you go into your lodge you will find all of your people there, and when they see you, tell them not to cry or make any kind of noise. Your own sister will be there and you must tell her to go after your friend's wife. She will not refuse your sister, but come right along with her." They started out and Buzzard told him to shut his eyes again. When Buzzard told him to open them he could hear his friend singing, and he knew it was he because he recognized his voice. When they came near to his home Buzzard told him to get off of his back. He did, and went straight to his lodge, and when he went in his sister was the first one to meet him. When she came to him she began to cry. He told her not to cry, but to keep quiet. He told them how his friend had treated him and how Buzzard had taken pity on him and rescued him. When he had finished he told his sister to go and tell the woman to come. She went and told the woman that she was wanted. She did not hesitate, but went along with the girl, and they both came in and the woman saw her husband's friend, whom she thought was killed, sitting with the others. The woman stayed with this man and did not care to go back to her former husband any more.

The husband was very sorry that he had told the stories to the head man and the chief. Many times after this these men went out on the buffalo hunt, and some of the others always watched him closely to see that he did not harm any one else. Finally they noticed that every time they went out he killed one buffalo first, and then did not take any of the meat, but would cut it up or dress it as though he were going to take it, and then would scatter the meat as though he were dividing it out to some people. The people began to wonder what he did that for. After he had prepared and scattered the meat of the first buffalo he had killed he would go on and kill another one, and then he would take his meat home. After people had seen him leave the meat of the first buffalo many times some one asked him why he did that. He would not tell, but one time his uncle came and asked him why he had done that so many times, and he told him all about it. He said he had lived with the woman many years, and when he should die his wife should drop dead, too.

47. THE TURTLE WHO CARRIED THE PEOPLE AWAY.*

One time the people broke camp and were traveling about looking for a village site. They traveled far until they came near the big water, and there they saw what they thought was a large rock. They decided to make their village near the rock, so they could use it as a dancing place. They had several dances on the rock, but not all of the people were there. One time, after they had been at the village for some time, they sent the crier to announce a big dance. All the people came and danced on the smooth, flat rock. While they were dancing they noticed that the rock began to move. They watched it and soon saw a big head and legs appear from under it. Then they knew that they were not on a rock at all, but on a big turtle. They tried to get off, but found their feet stuck tight. They cried and called for help, but the turtle carried them down into the water and drowned them.

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*Told by Wing.

48. WHY DOGS HAVE LONG TONGUES.*

A long time ago, when the animals were like people, dogs were noted for telling everything that they knew. In those days there were not so many dogs as now, but the best families always had a few hounds to take with them on the hunt. A man, Running-Water, who was a great hunter, wanted a dog to help him hunt, but he would not have one, because he hated to have some one always tattling on him and telling everything that he did. One time he saw four little pups and he decided to take one of them and try to teach him not to talk so much. He took the pup home, and every day, when he played with him, he would talk to him and try to teach him not to be a tattler like other dogs. The pup grew and was soon big enough to be taught to hunt. Running-Water began to take him out to hunt rabbits and small game. Every time the man killed any game the dog would sneak home and tell; then he would return to Running-Water in a circuitous way and come up to him from behind, as though he had been hunting all the time. Running-Water knew that the dog was trying to deceive him, and he whipped and scolded him. After each whipping he would stop running off and tattling for a little while, but soon he would begin again.

After a time the dog was big enough to go far away into the high timber to hunt with his master. One day Running-Water told his mother to prepare a large quantity of food, for he and his dog were going to the mountains to hunt and would be gone many weeks. He loaded several horses with provisions and started out, with his dog for his only companion. After three days of traveling they came to the mountains and made camp. They hunted several weeks and killed many big animals, and then started home. After a day's journey Running-Water missed his dog. He called him and searched for him and then went back to camp, thinking that he had perhaps gone back. He could not find him there, and so he gave him up for lost and again started home. He did not think the dog had gone on home ahead of him, for he thought that he had broken him of the habit of running home and telling everything; but when he came home he found the dog there. He had been there a long time and had told many big stories about the number of bears, mountain-lions, deer, coyotes, and other animals that they had killed. Running-Water was more angry than ever before, and he said, "I will make that dog stop tattling so much." He caught the dog, gave him a hard whipping, and told him he would

* Told by Hinie.

pull his tongue out the next time he came home and told everything. Then, being still angry, he caught hold of the dog's tongue and pulled it as hard as he could, and then he ran a stick across his mouth. Ever since then dogs have had long tongues and big mouths.

49. WHY HAWKS HAVE THIN LEGS.*

Chicken-Hawk was a poor hunter and never succeeded in bringing his family more than a little mouse or some game that he had begged from another hunter. One time he met Eagle and asked him if he would not help him kill an antelope that he had seen not very far away. Hawk pretended that he had killed many such big game before, and acted as if he were being kind to Eagle in asking him to help him. Eagle said he would if he could have half of the meat. Hawk said that he could, and so they agreed to go hunting for the antelope the next morning. Hawk went on home, and when he arrived he told his family that he had shot an antelope through the head, but that he could not kill him, and so he had run him into a place for the night, and that he would return in the morning and kill him. Hawk arose the next morning and went to the place where he was to meet Eagle. They started on the hunt and hunted half a day. They found the antelope in the mountain. Eagle killed it, and then Hawk came down and they divided the meat. Eagle took his meat and went away. Hawk took his meat and went straight home to show it to his family, for he was very proud of it. He told them that he had met a person who had never tasted antelope meat and who was a poor hunter, and so he had given him part of his meat, but that the person promised to pay him back some day. His family were so well pleased that they told every one what a good hunter Hawk was. One time, after the antelope meat was gone, a friend, who had heard what a good hunter Hawk was, came to visit him, especially to see if the reports were true. Hawk hunted all one day, but returned with only a mouse. The friend refused to eat the mouse. Again Hawk hunted all day, but could not find anything. As he was returning home he felt so ashamed, that he cut some of the meat off of his legs to take home for his friend to eat, rather than admit that he had not found any game. For that reason hawks have no meat on their legs.

* Told by White-Bread.

50. THE POWER OF BUFFALO AND BEAR.*

One time when the animals spoke many languages, and yet understood one another, Bear and Buffalo met. They commenced telling each other about the powers that each received from the Father and when these powers should be used. Said the Bear: "Once upon a time I was a human being and lived like a human being, and went with the people from place to place. When they camped in the open, my family always made a camp near by in the timber or mountains, for we liked to climb the trees and play among the rocks. One night I had a dream. I dreamed that I was as you see me now, and I heard some one telling me of the many things that I had within my power to do. I was shown the place where I should stay, and I was given the paws and claws and the sharp teeth which I now possess. Then I dreamed that a human being was pursuing me and shooting at me with his arrows, and I knew that he was trying to kill me for food, as he does any other animal. I awoke from sleep and found that all I had dreamed was true, and from that time I have been as I am now. I left the people and began a new life in the mountains and woods, and from that time the people have hunted me and have tracked me with dogs. Now they call me Bear, meaning 'the mountain animal.' I have told you all." Buffalo began to speak: "I, too, was like a human being and my ways were like their ways when we first came to dwell upon the earth. My people were called the Buffalo people because our oldest chief was named Buffalo. One time our chief was taken away from us and we never knew what became of him, though we were told that the Great-Powerful-One had taken him to another world, and that some day we were all going to that other world, and that we would meet our chief there. We lived with the people and traveled with them, going behind them. The people began to enter this world, but we were forbidden to enter because some one had made a mistake that caused us to stay back where we came from. We found out that the person who had made this mistake was Coyote, and so our people began at once to pray that the Father would give him powers and teach him so that he might enter the world and take us along, that we might be with the people. We do not know how we came to be as we are now, but we know that in order to be in the same world as the people are we had to change into wild animals, and that for the love of the people we had to be their game, and we were to be killed and eaten by them. Then we were given powers to be dangerous, and these horns on our heads were given to us to fight with."

* Told by White-Bread.

Then Bear asked Buffalo if he could show just what he did when he was very angry or when he wanted to hurt or kill any one. Buffalo began to throw up the earth and strike the ground with his sharp horns. Bear sat watching him, and all at once, before he knew what had happened, he was falling to the ground and Buffalo was coming at him again. When he had fallen to the ground a second time Buffalo asked him if he saw him when he first started after him. "No," said Bear. "Well," said Buffalo, "I think you ought to show me how you use your powers when you get angry." Bear began to go through his movement, and Buffalo sat watching him. Bear began to walk back and forth and look at Buffalo with angry eyes. Finally he began to move very slowly toward a small tree which was near by, and when he reached the tree he grabbed hold of it and with his sharp teeth cut it down. Before Buffalo knew what had happened Bear was upon him and he was trying to get up from the ground, but Bear held him down until he was ready to give up. Finally Bear let him go, saying, "That is the way I do when I get very angry, but I would treat you worse than that if I wanted to kill you." Bear and Buffalo parted and went to their homes.

51. HOW RABBIT STOLE MOUNTAIN-LION'S TEETH.*

One time when Rabbit's grandmother had gone off and left him alone he decided to wander about and see what he could see. He went along until he came to the home of Mountain-Lion. Mountain-Lion was not at home, so Rabbit went in and hunted about. He finally found Mountain-Lion's teeth and he took them and ran home with them. He was glad to find them, for the other animals were afraid of Mountain-Lion on account of his sharp teeth. Rabbit showed the teeth to his grandmother when he reached home, and said: "Now, grandmother, Mountain-Lion will soon be after his teeth, and we must fool him some way or he will kill us." Rabbit thought for a while; then he said: "Build a fire just outside the door, put a big kettle of water on the fire, and then put some stones into the water and boil them. When Mountain-Lion comes he will ask what you are going to do with those stones. Tell him that I have a guest in the lodge who is going to eat them. I will talk to myself in the lodge as though I were entertaining a friend, and when Mountain-Lion asks who my friend is, say 'Chief of all the beasts.'" The grandmother made a big fire and put the stones on to boil. Finally they heard a big noise, and Mountain-Lion came tearing through the bushes and came straight to the old woman. He asked her if Rabbit was at home, and she told him that he was inside talking to his friend and guest.

*Told by Wing.

Then he asked what she was going to do with the stones, and she told him what Rabbit had told her to say. He asked who the friend was, and she told him, "Chief of all the beasts." "Oh, yes, I know him," he said, and at the same time backed off a little, and then he turned on his heels and ran as fast as he could.

52. RABBIT AND THE DANCING TURKEYS.*

One time while Wild-Cat was out hunting he came upon Rabbit in the tall grass. Rabbit and Wild-Cat were enemies, and so they began to fight. Soon Wild-Cat had Rabbit down and was about to kill him, when Rabbit said: "How would you like some nice Turkeys to eat?" "That is just what I have been looking for," said Wild-Cat. "Well, I know where there are some, and I was just about to catch some when I met you. Now, if you kill me they will all get away. You had better spare my life until I show you how to catch the Turkeys; then you may do what you please with me." Wild-Cat agreed, and so Rabbit told him to stand still while he sang the Turkey dance song. After he had sung a little, he told Wild-Cat to lie down and pretend to be dead; that he would tell the Turkeys that he had killed Wild-Cat, and wished them to dance around him with closed eyes. While they danced, Wild-Cat was to jump up and grab all he wanted. Soon the Turkeys heard the song and came to see what it was about. Rabbit told them that he had killed the great turkey-eater, Wild-Cat, and that he wanted them to dance a victory dance around him. Rabbit continued his song, and as he sang the Turkeys danced. Wild-Cat peeped and saw one big one dancing near him. He jumped to get it, and as he grabbed the Turkey, Rabbit ran away through the grass, and so escaped from Wild-Cat.

53. ADVENTURES OF COYOTE.†

In the beginning of the world there were many, many people, and the people held councils to decide how things should be. There was one man, named Coyote, who always had something to say on every subject. At one council this question came up: "How and what kind of rain should be in the world?" One of the men said that it should rain in the form of lead balls, which would be very dangerous, and so when the rain came the people would have to stay at home. Then Coyote arose from his seat and said: "If it should rain nothing but lead it would be very dangerous for my people, because they do not stay at home very much, and as for myself, I might be carrying a big deer to my family to eat when the rain begins to fall and I would cer-

* Told by Wing. † Told by Moon-Light.

tainly be killed. I say, let it rain in drops of water. Then we can be caught out in the rain and get very wet, but we will soon be dry again, and the wetting will be good for us." The people accepted Coyote's suggestion, and so it is that it rains in the form of water.

When the council was all over and the people went to their homes, Coyote made up his mind to go out and visit some of his friends. He traveled until he came to the mountains. He saw smoke coming up among the mountains, as though some one was making up a big fire, and he thought he would go up and see who was living there. When he came near to the place he saw some one sitting by the fire. It was the great, powerful Bear. Coyote went closer, and Bear asked him if he was the person who was called Coyote, and Bear told him that if he was that he was going to kill him, for he had heard many bad things about him. Coyote told Bear he was not the person, but that he was the son of a great and powerful medicine-man. Bear did not believe him and decided to kill him. When he was about to kill him, Coyote told him to wait until his father saw him, for he might have something to say to him before he died. This happened at sunrise, and when the sun was just peeping over the hilltops Coyote said to Bear: "Now you may kill me or do as you please with me, because my father is watching me." Then Bear began to back away, and as he did so, Coyote began to go nearer and nearer to Bear. Finally he began to push him with his elbow, at the same time saying: "Now kill me while my father is watching me." Bear thought that he must be a great man, if he was the son of the Sun, and he wondered how he received his powers from the Sun. He became frightened and gave Coyote many things to eat, and then Coyote told Bear to come and make him a visit some time, whenever he felt like going anywhere. A long while after this, Bear found out that the person who made a visit to him was not the son of the Sun, but that he was the man Coyote, whom he wanted to kill. Bear was more angry at him than ever, and so he thought he would fool Coyote some way by going and visiting him and killing him if he could find his home. Bear did not find his home, because Coyote was always moving from place to place, for he knew that Bear was after him, and that he would kill him if he could catch him.

While Coyote was moving from one place to another he came down to a large lake of clear, cool water, and after he had been there for some time he started off a little way from the lake. While gone he saw some one coming up toward him and, as he was very cowardly, he started to run away. The person was not his enemy, but a friend of his, Mountain-Lion. He called Coyote back, and so he came, and he told his friend that he was very hungry, for he had had nothing to eat for a long while Mountain-Lion asked him to go along with him, saying that he would find something for him to eat soon. They both went to the lake, and when they came down to the water Mountain-Lion told Coyote that he was going to kill a young horse. In those times there were many herds of wild horses, and at the lake there was a certain place where the wild horses drank. Near the place where the road led to the water there was a large tree, and the horses passed under the tree as they went down to the water. Every day at about noon Mountain-Lion would climb the tree and then pounce down on a young horse and kill him. As Mountain-Lion and Coyote drew near to the tree Mountain-Lion told Coyote to place himself where the wild herd of horses could not see him, and so he did, and Mountain-Lion climbed the tree. Soon Coyote saw dust rise up from the ground and he heard something like thundering, and later he saw many hundreds of horses coming down to the water. As the horses were passing under the tree, Coyote saw Mountain-Lion jump out of the tree and pounce upon a young horse and kill it. Then Mountain-Lion and Coyote both had a fine dinner. That day, after they had eaten, Mountain-Lion told Coyote to continue on his way; but Coyote did not want to leave his friend, and so he asked Mountain-Lion if he could give him power so that he could kill a horse, too, and eat it when he was hungry. Mountain-Lion told him he would. They stayed there until the next day, and at about noon they both went down to the lake again, and went to the tree, and then Mountain-Lion showed Coyote how and what to do when the horses should come. He taught him how to climb the tree, and then he went out to place himself where the horses could not see him.

Soon they began to come from different directions, and as they filed down to the water Coyote picked out a fat young horse, and as they were coming up from the water he jumped on it and killed it. They had another fine dinner, and then Mountain-Lion said to Coyote: "Do not try to kill a three or four year old horse. If you jump on one that is three years old you can not kill him and you may lose your own life. Try to kill one that is one or two years old and you will succeed every time." Coyote left his new friend and went on his way. The next day, while he was alone, he began to get very hungry, and so at about noon he went down to the lake to kill a horse. While he was on the tree he said to himself: "I wonder if it would be dangerous for me to kill one of the large horses. I may be stronger than Mountain-Lion, and so I will try to kill the largest horse and I will show Mountain-Lion that I am not so small as I look to him." The horses began to go down to the water, and Coyote waited and waited for the chance to jump upon the largest horse in the herd. Finally a large horse came, and when he was right under the tree Coyote jumped upon him. It was but a short time until the horse threw Coyote off from his back, and when Coyote was down on the ground the horse kicked him under the jaws and went off. As Coyote was about to die, Mountain-Lion, who had been watching Coyote all the time, came up to see what was the matter with him, and when he came up to him he saw his jaws to one side. Mountain-Lion asked Coyote what he was laughing about, and asked him if he was able to kill another five-year-old horse. Coyote lay there for a long time before he was able to move. Finally he arose and decided to leave the place, never to return to it. As he was going along a small stream he heard some one up in a persimmon tree, and so he thought that he would go over and see who it was. He found Opossum in the persimmon tree eating persimmons. Coyote went under the tree and asked Opossum to throw down some persimmons to him. Opossum refused and laughed at Coyote and began to play with him. Opossum would take one persimmon and eat it, and then he would throw the seeds down to Coyote. Finally Coyote became angry at Opossum and wished he could get him down from the tree. Sometimes Opossum would get on a small limb of the tree, and then drop down as though he was going to fall to the ground, but he would always catch himself by wrapping his tail around the limb. He kept on doing this to torment Coyote for a long time, until he climbed out on a dry limb. He threw himself off the limb again and said to Coyote: "I am falling off, sure. I am coming down," and just as he let himself off of the limb it broke off and down came Opossum. Coyote was upon him and gave him a good beating, and then he left him to die. Opossum fooled Coyote, for he was not hurt at all, and when Coyote went away Opossum jumped up and climbed the persimmon tree again. After a while Coyote looked back to see if Opossum was dead. He could not see him, and so he went back and found that Opossum was gone. He looked up in the tree, and there he saw him laughing at him again.

54. COYOTE ESCAPES AN IMAGINARY FOE.*

One time Coyote went out hunting buffalo. While he was going through the timber he found Turkey up on the top of a tall tree. He told Turkey that he was going to kill him if he did not get down from the tree. He said: "If you don't come down I will climb the tree. If you fly to another tree, I will break it down at once, and will certainly kill you; but if you fly toward the prairie I can not harm you, for I have no powers to kill anything on the prairie." Turkey believed

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* Told by Wing.

all that Coyote said and started out toward the prairie. Coyote was right under Turkey all the time. At first Turkey flew up so high that Coyote thought he was going to lose him, but after a long flight Turkey kept coming down lower and lower, and finally came down on the ground. Then Coyote was not very far behind and he caught up with him and killed him. While Coyote was eating Turkey, he happened to look around to make sure that no one was watching him. He thought that he saw somebody standing behind him making motions as if trying to strike him. He started to run without learning who it was. Every now and then he would look back to see if he were out of his reach. Every time he looked back he thought he saw the man right after him, ready to hit him. He ran with all his might, trying to get away from him. Coyote had been given power at the beginning of the world to run without decreasing his running powers. Coyote began to think that some great, powerful man was behind him and that he had to die. He had run eight times. The ninth time he thought he would run farther than usual. Again he looked around, right and left, and thought he saw the man just about to hit him. He started to run his best again, but his running powers were decreasing continually. He was then running for the tenth time; but it was all in vain, for the man seemed to be right up with him. Then Coyote thought he would fool the man, so he kept dodging right and left, but the man seemed to be near him all the time. When he started to run the twelfth time he had not gone far when he gave out. He rolled and turned over on his back and begged not to be killed. He fell over on his face, then heard something crack, and he thought it was one of his teeth, but it was only a turkey feather which had stuck between two of his upper teeth, and it stuck up nearly straight and level with his head back of his right eye. At first when he looked back he had thought surely that some one was standing behind him ready to strike him. When he found that he had been fooled by only a turkey feather, and had been running himself almost to death for nothing, he was very angry. Ever since, Coyote has looked wild, and when he runs he starts out very slowly for fear he may have to run a long distance, and when he runs he first looks around to the right and then to the left to see if anybody is near him. Most often he looks to his right side while running. When Coyote reached home he told his family and others that he had been running after a great big mountain-lion, and that he had killed it. He said: "If there had not been so many trees I would have brought it home."

55. COYOTE GOES FISHING.*

One time Coyote went out hunting along the river and saw some one walking along its banks, carrying something on his back. When he came nearer he saw that it was a man carrying a fish. Coyote came to him, and said: "How do you do, my friend? Where are you going? Where have you been? Where did you get that big snake?" "Well," said the man, "I have been out fishing nearly all night, and finally I caught this fish. I was so tired that I did not care to catch another." "What!" said Coyote, "do you call that a fish? How did you get hold of it?" "Well," said the man, "I will tell you how to get them. When evening comes go down along the edge of the river and break a place in the ice just big enough to put your tail in, and stay there until I come to see you again." That same evening Coyote went to the place and found the man waiting for him. It was getting dark. The man told Coyote to sit down by the edge of the water, while he was breaking the ice. Coyote did as the man told him. He did not know that this was a man whom he had tricked some time before and that he was trying to get revenge. The man left Coyote sitting by the bank fishing all that cold night. Toward the middle of the night the water began to freeze on Coyote's tail, and toward morning the ice got thicker and thicker, and when morning came Coyote tried to get up from his seat, for he was very tired, but he could not. There he was, trying in every way to get free, but he could not move. When the man came he said to Coyote: "How are you getting along? Are you catching any fish?" Coyote replied: "I think I have caught two or three of them, but can you help me to get them out on dry land?" "Yes," said the man, "of course I will, although I want to talk to you before we get the fish out of the water. You remember that a long time ago you were one of my best friends, but finally you tricked me, and now I am getting even with you. You will have to die, for I am going to kill you." "My friend," said Coyote, "I think you are mistaken. I do not think I am the man who played the mean trick on you. You know very well that I never betray my friends while I am able to see. If you will let me go this time I will go and bring the man you are looking for, and I will come back to-morrow evening and assure you that I am your friend." "But," said the man, "I do not see how you are going to get loose to go, do you? I will look for the other man myself, and I will do to him just as I am going to do to you." The man went back to his lodge to get his bow and arrows. When he returned to Coyote he took one of the arrows

* Told by Wing.

out and showed it to him and said, "You see this?" He began to sing the song that warriors sing just before they kill their enemies. When he had finished the song he shot and killed Coyote.

56. COYOTE HUNTS GEESE.*

Coyote was once a man and lived with the people. His great-grandfather named him Coyote, but because he did wrong the people came to dislike him and began to call him coward. The reason the people did not like him was because he was always scheming and trying to cheat some one. One time he went out to visit his best friend, and when he arrived at his friend's lodge he found that his friend had been feasting on white geese. "Where did you get these white geese?" "Well," said his friend, "I catch them every evening near the lake. Would you like to go with me this evening to catch a few of them?" "Yes," said Coyote. His friend then said: "You go on home and come back this evening. We will then go together and I will show you where the geese always come in the evening, and I will see that you have a good time, too." "Oh, you do not have to show me how to get them; I can get them all right. All you have to do is just to show me where they are," said Coyote. "All right," said his friend, and Coyote was pleased, for he thought he was going to have a very fine, fat bird for supper that evening. He danced all the way from his friend's home to his own. As soon as Coyote was out of sight the friend began to carry out ashes from the fire and place them near the lake, where he formed them in the shape of white geese. Just before it was evening he went out and put some coals under the ashes, and in a little while the coals burned up, but the fire could not be seen from the outside. When Coyote came to his friend he found him laughing and feeling in high spirits. "Well," said Coyote, "are you ready to go and catch a few white geese? I am ready to make a long jump and I think I can get two at once." "Well," said the friend, "I am ready, too. We will go now." They started out, and as they approached the place the friend began to go slowly, taking the lead, and when they came to the place he pretended not to see the first pile of ashes. Finally Coyote saw the first pile, came closer to his friend and began punching him in the back. Both stopped and Coyote said: "I guess I will have to kill this first one, and if I catch him I will take him for my supper." "All right," said the friend. Coyote began to get down next to the ground, going nearer and nearer to the pile of ashes. When he was about to jump, the friend began to laugh. Coyote paid no attention, but jumped on the pile of hot ashes and burned himself. He began to run from the place. He was burned so badly that he ran until he killed himself.

* Told by Wing.

57. COYOTE IMITATES HIS HOST.*

In the days of old, when animals were like people and talked and visited each other, Coyote and Raven were great friends. One day after Coyote had grown weary of hunting for game and finding none, he went up to the top of the mountain to see his friend Raven. Raven had control of the buffalo and was always seen with the herds. (Now, since the buffalo has gone from the earth, Raven has disappeared and is seldom seen any more.) Raven invited Coyote to enter, and when he saw Coyote weary and sad and silent he arose, took an arrow, shot it up into the air, and then stood waiting for it to come down. It came down and pierced him under the right arm. He drew the arrow out and with it came buffalo meat and fat. He gave the meat to Coyote, who ate heartily. Then Coyote smacked his mouth, arose, and said that he must be going, but before he went he gave Raven an urgent invitation to come over and make him a visit, and Raven promised to come.

When Coyote went home he began making a bow and arrow, and when he had finished them he put them away until Raven should visit him. One day Raven bethought himself of his promise, and so he left his home in haste to pay Coyote a visit. Coyote received him with joy. After they had talked about many things Coyote said: "I have no meat, for I did not expect you, but if you will wait I will soon have some for you." Coyote took his bow and arrow and shot the arrow into the sky, then stood waiting for it to come down. Raven watched him and said never a word. The arrow came down and struck in Coyote's thigh. He ran away screaming with pain and left his guest alone. Raven waited a while and then went home without any meat, but in very high spirits notwithstanding, for Coyote's performance amused him greatly and he chuckled to himself as often as he thought of it. Coyote continued to run until he pulled the arrow out of his thigh; then he took the arrow and broke it to pieces. He never went back to see Raven, and time passed on and none of Coyote's friends saw him, and they all wondered what had become of him. At last he grew so hungry that he had to go out for food. He found none, and so he went to visit another one of his friends, for he had many. Black-Mountain-Bear received him graciously when he came to his home and asked him in. Bear said: "I regret that I have no meat to offer you." As he spoke he leaned against a persimmon tree that was weighted down with many ripe persimmons, and as he leaned against the tree the ripe fruit fell to the ground. Bear smiled and asked his friend to eat. Coyote ate many,

* Told by Wing.

for he was very hungry. When he had finished he thanked Bear and said that he must be going, but before he went he insisted that Bear come to see him, and Bear promised to come soon.

Coyote wandered all about looking for a persimmon tree. He could not find one with any fruit on it, and so he decided to take one without fruit. He cut the tree down and carried it to his home, where he set it up; then he went out to look for persimmons. He had stolen some from Bear's home, but he had not stolen enough. When he found more persimmons he took them home, and climbing the tree he placed the persimmons all over the tree, so that they looked as though they had grown there.

Black-Mountain-Bear was out hunting one day, and as he was near Coyote's home he remembered his promise to visit him, and so he ran over to see him. Coyote was glad to see him and asked him in. "I am so sorry I have no meat for you," he said, "but if you will wait I will try to get you something to eat." Coyote begàn to bump against the tree with his head. He hit harder and harder, but the persimmons would not fall. Finally he arose and shook the tree with his hands, though it embarrassed him to have to do this. He gave the tree a big shake and over it fell, hitting him on the head. He pretended that it did not hurt and went about gathering up the fruit for Bear, though he could hardly see for pain. Bear ate, though he could hardly swallow for laughing, for Coyote's head kept getting bigger and bigger. After a little while Bear said that he must be going, for he was afraid to stay longer for fear Coyote would see him laugh. After he had gone Coyote sat down and held his sore head, but he felt happy notwithstanding, for he had furnished food for Bear.

58. COYOTE IMITATES HIS HOST.*

One morning while Coyote was out looking for something to eat he came to a grass lodge. Thinking that there might be food inside, he decided to go in and pay his respects to its owner if he should be there; if not, help himself to food. He entered and saw a man walking about with a light on his head. At once Coyote called out: "Say, friend, your head is on fire, and you and your house will burn up if you don't look out." The man smiled and replied in a calm voice: "I have always worn this light on my head. It was given to me in the beginning. It will not burn anything." Then the man, who was Woodpecker, gave Coyote something to eat. After Coyote had eaten all he could, he arose and said that he must go. He asked Woodpecker to

* Told by Wing.

come over and make him a visit, and Woodpecker promised that he would. Some time later Woodpecker remembered his promise and so started out to find Coyote's lodge. He found it, and Coyote, much pleased, invited him to come in and be seated. Woodpecker entered and was surprised to see a big bunch of burning straw on Coyote's head. "Ah, take that off. You will burn your head." Coyote only smiled, and replied in a calm voice: "Oh, no; that will not burn my head. I always wear it. I was told in the beginniug that I would wear a light on my head at nights so that I can do whatever I like to while others are in darkness." He had no more than finished speaking when the hair on his head caught fire. He began to scream and try to put it out, but could not. He ran out of his lodge screaming for help. Woodpecker waited for him to return, but he did not come.

59. COYOTE, THE DEER, AND THE WIND.*

One time when Coyote was out hunting something to eat he met Deer. Deer asked Coyote where he was going, and Coyote told him that he was going out hunting. Deer asked Coyote how he killed his game, for he noticed that he carried no bow and arrows. "I can kill anything I can get my hands on," said Coyote. "But how do you get close enough to get your hands on your game?" Deer asked. "Sometimes I run the game down, sometimes I catch them asleep." Deer said: "I am considered good food; even the human beings are very fond of my flesh. If you can catch me I will let you kill me and eat me." Deer started to run, and Coyote started after him, but soon lost sight of him and gave out. He went on home, but he could not help thinking of Deer's offer, and wondering how he could catch him. He wandered about trying to find him asleep, but never did. One time, after Coyote had been out searching to find Deer asleep, he grew very tired and lay down in the tall grass to take a nap. When he awoke he heard some one singing near by. He was badly frightened and sat up straight and rubbed his eyes and peeped about. He saw no one, but as he sat still and listened again he heard his name mentioned in the song. He jumped up and ran as fast as he could; yet he always heard the voice singing in his ears, just as near as when he woke up. He ran as fast and far as he could; then he dropped down to die. While he was panting, he heard the voice again, and it was so near that he heard these words: "If Coyote ever kills a Deer he shall be as fleet as he, and I who am singing am going to give him power to catch a Deer. I am the Wind." Coyote's fear vanished, and he arose and barked at

* Told by White-Bread.

the Wind in a loud voice, to give thanks. His weariness left him and he started out to find Deer. He traveled all day, but could not find him. At night he came to a camp, where he stole a buffalo robe. He put the robe over him and then went on to look for Deer. Down by the river he thought he saw him. He went another way and slipped round a bend in the river until he came close to Deer. He reached out his hands to grab him and said, as he caught hold of him: "I have you; I thought you said I could not get you." To his surprise he found that he did not have Deer, but the man whose robe he had stolen.

The man took Coyote home with him and made him work for him and his sister, and treated him very cruelly, because he had stolen his robe. One time while the man was out hunting, Coyote went into the lodge and said to the sister in a loud, angry voice: "Pack up your clothes; I am going to take you to my home as prisoner, and you will have to work there as I have worked here. Your brother is killed and now you must come with me." The girl was frightened and obeyed. They started toward Coyote's home. Coyote went behind the girl with a long stick in his hand, and whenever she stopped or fell he hit her with the stick. The girl went on, though she was so tired and frightened that she could hardly move, and as she went she prayed that her brother was not dead, but would come and help her.

In the meantime the man returned home and found his sister and Coyote gone. He knew at once what had happened and started after them and soon caught up with them; for he had the power to travel as fast as the fleetest arrow, though Coyote did not know it. When he was almost up with them he shot an arrow in front of his sister. She saw it and knew that her brother was coming to help her; then she began to cry the more from joy. Coyote whipped her for crying and made her travel faster. The man saw Coyote strike his sister and heard the cruel words that he spoke to her. He went on a hill and then shot another arrow. Coyote looked up and saw him and became frightened even more than the girl had been. He dropped his stick and ran to the girl and begged her to let him carry her bundle of clothing, and begged her not to cry. The man came down from the hill and asked Coyote where he was going with his sister. Coyote said that the people had treated them so badly he had decided to take the girl to another village, where the people would be kind to her. He said that he was helping her along the way and had been kind to her. The brother of the girl did not believe Coyote, for he had seen his treatment of her. He told Coyote to take the bundle of clothes and put it on his back; then he told his sister to sit on the bundle. He put his bow-string through Coyote's mouth and gave the ends to the girl. She sawed the strings back and forth and the man ran along by the side of Coyote, whipping him, and thus they returned to their home. This man was the Wind, who had become angry at Coyote for stealing his robe and trying to catch Deer with it, instead of waiting for him to give him power.

60. COYOTE DIVES FOR MEAT.*

One time when Coyote was out hunting she killed a big deer. She cut the deer up and hid it in a tree while she went home to get her children to come and help her carry the meat home. Wild-Cat saw her kill the deer and hide it, and as soon as Coyote was gone he stole the meat and climbed a tree on the bank of the river, where Coyote could not see him. After a little while Coyote returned with all of her happy and hungry children. They looked every place for the meat. The children were angry at their mother and said that she had lied to them. While they were abusing her, she saw the reflection of the meat in the water, and, thinking that it was the meat, she told her children to sit still while she dived for it. She told them that it had fallen into the water, but that she could very easily get it if they would only be quiet and wait. She dived and struggled in the water, reaching for the meat, but never getting it. Finally she sat down upon the bank to rest, wondering how she could dive deep enough to get the meat. After she had rested she told the little Coyotes to bring her some stones. She tied the stones about her neck and dived again. The Coyotes waited a long time for their mother to come up, but she did not come. After a while they saw some excrement on the water, and they laughed, for they thought it was the meat their mother had thrown up. When they laughed Wild-Cat laughed at their foolishness. They looked up in the tree, and there saw Wild-Cat and all of the meat. Wild-Cat told them that their mother was drowned. Then they began to cry, but Wild-Cat told them not to cry, that he was going to come down and take care of them. He climbed down and brought the deer meat with him. He gave the little Coyotes all they wanted and then took them home. After that, whenever he killed any game he always took some over to the Coyote children, and fed and cared for them until they were grown.

61. COYOTE, THE GEESE, AND THE WOODPECKERS.*

Coyote was returning home after an unsuccessful hunt. He was going along sad and discouraged, when he heard some one laughing and playing. He listened for a while, then decided to go and enter into the fun, so that he might be cheered up. He ran over a little hill, and there on

* Told by Wing.

the other side was a big lake, and on the surface several white Geese were playing. He sat down behind some brush to watch them. They were trying to see which was the strongest. One would get on the back of another and fly, trying to see which could fly the farthest. Coyote decided not to enter into their play, but to try to catch them and take them home to his family. The Geese had seen Coyote coming, for they have power to see a long distance, but they pretended that they had not seen him and did not know that he was hiding behind the brush.

Coyote watched them for a long time, trying to think of some plan whereby he could catch all of them. Finally he began to grin to himself, for he had thought of a plan that he thought would work splendidly. He limped out from the bushes, pretending that he had been hurt and was almost dead. The Geese, hearing him crying, turned and saw him come limping toward them, and they all began to swim out into the water. When they were out far enough for safety one turned and asked Coyote what was the matter with him. He answered: "I am going to be killed if I do not get across the water. I must get across, not so much on my own account as others, for if I am killed all the rivers and lakes will dry up and there will be no water for any one. I should hate to die and cause all of this to happen."

The Geese thought for a while, and then decided to take Coyote and throw him into a deep hole; for the Geese were very smart people in those days and they knew that Coyote was lying to them. One old Goose, who was very strong, went to the bank and told Coyote to get on his back if he wanted to go across the water. Coyote said that he was too heavy for one to take him across; that he would not trust himself to one. The Goose told him to get on if he wanted to go across the water; that they did not have much time to fool away with him. There was nothing else to do, so Coyote got on the old Goose's back. The Goose flew up in the air so quickly that Coyote did not know what had happened until he was away up in the air. All the other Geese flew up, and they all took turns in carrying him. They flew over a timbered country back from the lake, and when they were directly over a large hollow trunk of a tree they dropped Coyote. He fell into the hollow trunk and could not get out. He began to pray for power, and asked everything all around for help, for he was frightened almost to death and thought he would never get out. A Fly flew into the hollow tree, and he prayed to him to give him any power that he had which would help him out of the tree. The Fly said that his power was too weak to help Coyote, but that he would go to a friend of his and bring him to help Coyote. The Fly flew away and soon returned, saying that his friend was coming. Finally he heard a bird on a tree near by, and he peeped out of a small hole in the tree and saw that the bird was a Woodpecker. The Woodpecker called to Coyote and asked him if he really wanted to get out. Coyote answered in a weak voice that he did. The Woodpecker said that he had to go and get some one to come and help him. Soon Woodpecker returned with some of his brothers, and they began to peck a hole in the hollow tree. At last the hole was big enough for Coyote to get out. He told them to stick their heads in and see if they thought he could get out all right. They stuck their heads in and Coyote bit their heads off. After he had eaten all the Woodpeckers who had worked to make the hole for him, he escaped.

62. COYOTE AND RABBIT KILL A BUFFALO.*

Rabbit and his grandmother lived by themselves, and Rabbit often went out to hunt to get something for them to eat. He began to go pretty far from home, and his grandmother scolded him and told him not to go so far, but to remember that he was little and might be killed. Rabbit did not pay any attention, for he knew that he was a good runner. One time he went far away, but could not find any game, and so he turned around to go home. As he went he played along the way and sang to himself. Coyote was out the same day looking for something to eat. He was just about to give up and go home when he heard some one singing. He looked all about and saw Rabbit. He grinned to himself and quietly slipped up behind Rabbit. When he knew that he was so close that Rabbit could not get away, he yelled "Bo!" at Rabbit and made a grab for him. Rabbit was badly frightened, but he determined not to give up. He said: "Coyote, don't kill me yet and I will tell you how to kill some good game. I can not do it alone, and I have just been wishing that you would come and help me with my scheme." "What is it?" asked Coyote, very much interested. "I know where there is a big fat buffalo that we can kill if you will go with me." Coyote went, first telling Rabbit that if he lied to him he would kill him at once. Rabbit led the way to a place where an old buffalo stood. They went up to the buffalo, and Rabbit told Coyote to climb into its anus. Coyote obeyed and Rabbit followed. When inside, Rabbit told Coyote to begin to bite and eat the buffalo's sides. They both began and soon the buffalo fell dead. Then an old man ran up to the buffalo and began to butcher it. Rabbit told Coyote to hide in an intestine, and he hid in the bladder. When the man had cut up the buffalo he placed the intestines to one side, but threw the bladder away in the bushes. Rabbit crawled out of the bladder and escaped, but Coyote was discovered and killed.

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* Told by Wing.

63. COYOTE, MOUNTAIN-LION, AND RABBIT.*

One time, when Coyote was out hunting for something to eat, he heard something crying like a child. He ran to some rocks from whence the sound came, and there he found Mountain-Lion's den and her young left there alone. He determined to devour them, for he was very hungry, but he hesitated because he feared Mountain-Lion. At last hunger got the better of his judgment, and, saying to himself that he was not afraid of old Mountain-Lion, he killed and ate all of her children.

When the mother came back from the hunt with food for her young ones, she could not find them. She looked every place, and soon discovered Coyote's foot-prints. She knew at once what had happened. She started out to find Coyote, but he always escaped her. After she had followed him many days, she sat down on the bank of the river to rest. Not far away she saw some one and she at once recognized Rabbit. She determined to call Rabbit and ask him to help her catch Coyote, for he was the enemy of both. Mountain-Lion called to him in a gentle voice so as not to frighten him, and asked him to come to her, for she wanted to speak to him. Rabbit was afraid at first, but when Mountain-Lion told him that she wanted him to help capture Coyote, Rabbit came. They started along the river together. Soon they found a deer. Mountain-Lion told Rabbit to wait while she killed the deer. She followed the deer into the thicket, killed it, and then called Rabbit to come and help her cut it up. When they had butchered it, Mountain-Lion told Rabbit to cover her face with fat so that she could not be recognized; then to put the deer on her back. After Rabbit had done that, Mountain-Lion told him to get on top of the deer and to drive her around until they met Coyote. While they were crossing the prairie they heard some one calling, "Rabbit, where did you get your fine horse?" But Rabbit did not answer, and went on as though he had not heard the voice. Again the voice called, "Rabbit, did not you hear me? Wait, I say, I want to see your horse." Rabbit went on until Coyote, for it was he, had caught up with him; then he said, "This fine horse was given to me." Coyote said: "Get right off. That horse is mine. I lost it and you have found it. Get right off." Rabbit pretended to be afraid and jumped off. Just as Coyote was about to get on the horse, he stopped to bite a piece of fat off of its face. Then he recognized Mountain-Lion and started to run for his life, but it was too late. Mountain-Lion sprang upon him and killed him.

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* Told by Wing.

64. COYOTE BECOMES A BUFFALO.*

While Coyote was out hunting something to eat he met Buffalo, who was very powerful among his tribe. He was eating grass and looked fat and well fed. Coyote asked him if he would give him power to turn into a Buffalo and eat grass as he did. Buffalo said: "Yes, I will give you the power which was given to me by the Great-Father-Above, but when I give you the power you must not use it every chance you get, but only when very necessary." He told Coyote to stand facing the other way and not to move, but to be brave as he was. Coyote stood still, wondering what was going to happen to him. Buffalo began to throw up dirt with his hoofs and to act very angrily. He told Coyote to keep his eyes closed. Then he made a plunge toward him, and when he was about to strike him with his horns, Coyote jumped out of the way, and Buffalo passed him without touching him. He did this the second, third, fourth, fifth, and sixth times, but the seventh time he stood there without moving. He could hear Buffalo coming at him, but he stood there awaiting what would happen to him. Buffalo struck him and rolled him under his stomach with his horns and threw him up into the air. When he came down on his feet he was turned into a very young Buffalo. He began to eat green grass at once. Then the old Buffalo told him that if he wanted to turn into a Coyote again, he must find a Buffalo wallow, roll himself over two or three times, and then he would arise a Coyote. Again Buffalo cautioned him not to use his power too often, telling him that the power was good for only seven times, and he also told him that he must not give the power to any one else, especially to any of his own race. Before they parted the real Buffalo told Coyote to change back into a Coyote, and he did so, and then they both went on their way. Before Coyote had gone far from Buffalo, he wanted to try his power to see if he could use it alone. He did, and became a Buffalo. During that same day he tried his power three or four times, and before he had met any one he had tried it six times, and had turned himself into a Buffalo for the seventh time. While he was a Buffalo he met one of his own people, a famous Coyote, and so he went up to him and said: "Do not you want me to give you some of my power, so that you can eat grass as I do? You look as though you were very hungry." "Yes," said Coyote. "Well, all right," said Coyote-Buffalo. "Go off a short distance from me and stand there and face the other way. Do not run, but be brave as I am. Close your eyes. Now, I am

* Told by White-Bread.

ready," and so he started at him, but the other Coyote jumped out of the way every time until the last time came. Then Coyote stood his ground, and Coyote-Buffalo rolled him under his stomach, and they both went up in the air and came down on their feet. They were both Coyotes, and they stood looking at each other for a time; then they separated and went off.

65. COYOTE AND THE TURKEYS.*

Coyote was looking for something to eat, for he was hungry as ever. Finally, on his way, he heard a noise. He thought to himself, "Some people must be having lots of fun," so he made up his mind to go and enjoy himself with them. He went in the direction of the noise and he found many Turkeys. They were having fun by getting into a large sack and rolling down a steep hill. When the Turkeys saw him coming they said that they were going to put him in too. Coyote came and wanted to take part in the fun, for he thought it a good chance to kill some of the Turkeys. He let the Turkeys roll him down the hill two or three times; then he thought that his time had come to carry out his plan. He told all the Turkeys to get into the sack and he would roll them down the hill. Every one of them crawled into the sack, and then Coyote tied it fast at each end, so that they could not get out, and put it on his back and started for home. He had four young sons at home, and calling them to him he opened the sack and took out one of the Turkeys, saying: "You see this. I have that sack full of Turkeys. Build a big fire and we will have a feast." They built a fire, but did not have enough wood to make a big, hot fire. "We will go to the timber for wood, and you," speaking to his youngest son, "stay here and watch the sack." "Be careful not to untie the strings," said Coyote. Then he and his three sons started for the wood. After they had been gone a little while young Coyote thought he would look into the sack and see what the Turkeys were doing. He untied the strings, and just as soon as he untied the strings the Turkeys all ran out and flew away. Young Coyote did not know what to do, but finally he decided to put some dirt in the sack and fool his father that way. He went to work and filled the sack with dirt. His father returned and said, "Now, children, we will have a fine feast," and went to the sack to kill three or four more of the Turkeys; but when he opened the sack he found nothing but dirt in it. Coyote was very angry at his son, and he asked him how he had let the Turkeys get away, and the boy told him all about it. Coyote killed his young son and ate him in place of the Turkeys.

* Told by White-Bread.

66. COYOTE'S EYES ARE REPLACED BY BUCKEYES.*

One time Coyote was out hunting something to eat, and on his way he heard a noise and he said to himself, "I think those are some Turkeys that escaped from me some time ago. They will not get away this time, for I will kill them before I get home." And so he made up his mind to go and see what they were doing, and to catch them. When he went to the place, he found Ducks playing about in the water. When they saw Coyote coming they knew him at once, for they had often heard about him. They came out of the water and stood on the bank, and when he came up they asked him if he would like to play with them. He said, "Yes, that is just what I want to do, and I will show you some of my tricks after you show me some of yours." They debated what to play, and one of the Ducks spoke up and said: "We will play in the water. We will take one man and take his eyes out and let him dive into the water just as long as he can hold his breath, and as soon as he goes under the water we will throw his eyes into the water after him, and when he comes out from under the water his eyes will be in their place. How do you like that?" the Duck asked Coyote. "That is all right," said Coyote. "Well, we will commence now." The first Duck had his eyes taken out, and then he dived into the water and his eyes were thrown in after him, and when he came up he had them in their place. Then another took his turn, and so on until every one of the Ducks had tried, and then Coyote's turn came. His eyes were taken out and thrown into the water after him, and he came out with his eyes in their place. The Ducks were given power to do most anything that they wanted, but they had the power to do each thing only once. Coyote wanted to try the trick once more, but the Ducks did not want him to try it again, for they knew that their power was limited to one time. Coyote kept begging them, and finally the Ducks let him try the trick again, and so they took his eyes out and he dived into the water. The Ducks knew that they could not put the eyes in place again, and so they flew away and left Coyote. While he was going along he was talking and crying. He was asking some one who had greater powers than he to help him out of his trouble and to give him eyes again. Finally a man found him and he told him that he would help him all he could, and told him to wait there until he returned. He went off to find something with which to make Coyote some new eyes. He was gone for a while, and when he returned he had some green buckeye balls.

* Told by White-Bread.

He told Coyote to be brave once more, that he was going to hit him where the right eye was with the buckeye ball, and then where the left eye was with another ball, and then he would be able to see; and so he did, and thus Coyote's eyes were restored.

67. COYOTE AND TURTLE RUN A RACE.*

One time, as Coyote was returning from a long and unsuccessful hunt for game, he passed the home of his old friend Turtle. Being weary and hungry and in no hurry, he decided to stop and make Turtle a visit. Turtle invited him in and offered him something to eat, as Coyote had hoped that he would. While Coyote ate, Turtle stretched himself out to rest, saying, "I am tired out. I have just come back from the races." Coyote asked what races. "Our people have been having foot races down by the river. Have not you heard of them?" Coyote smiled at the thought of Turtle's racing and said that he had not heard of the races, and if he had he surely would have been there. "Who won?" he asked. "I did," said Turtle. "I have never yet been beaten in a race with my people." Coyote answered, "I have never been beaten either. I wonder how a race between us would come out." "The way to find out is to have a race," Turtle said. "I am willing, if you are. When shall we have it?" Coyote answered. They determined to run the race two days hence. In the meantime Coyote had finished eating, and so, promising to come on the second day to run the race, he departed.

When he arrived home Coyote sent his son to call all of the Coyote people and announce to them that his father was going to run a race with Turtle, and that he wanted them all to come and bet heavily on the race, for of course he would defeat Turtle. As soon as Coyote had gone Turtle sent his son out to announce that his father was going to run a race with Coyote, and that he wanted all of the best runners to come to his lodge. They all came and listened to Turtle's plan to beat Coyote in the race. Turtle arose when they came in and said: "We all know that Coyote is a good runner, but he is also a cheat. He has cheated us in many ways. Let us now cheat him out of this race. Will you help me do it?" Every one present agreed to help him. Then he continued: "This is my plan. I want each one of you to put a white feather in your hair just like the one I wear, and paint yourselves to look just like me. Then station yourselves at intervals along the course. Coyote will run with his head down, as he always does. One of you will start with him, but when he has left you far behind drop down in

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* Told by Wing.

the grass. Then the next one will jump up and run. Coyote will look up and see you ahead, then he will run until he passes you. Then the next one will jump up and run, and so on until the last one. I will be the last, and beat him over the goal." The Turtles talked over the plan, then arose and went home to prepare for the race.

The first day passed, and then the day came when they had to run the race. Early in the morning the Turtles stationed themselves along the way in the tall grass, and soon Coyote came. They began to discuss the distance they should run. Turtle wanted to run a long distance, but Coyote did not want to go a very long distance; he thought that he could beat Turtle in a short distance just as easily as in a long distance, and he did not care to tire himself. Turtle insisted, and so Coyote said that he would agree to any distance that he would mention. Many Coyotes came and began to bet on Coyote.

They started to run and all the Coyotes began to laugh, for their man was far ahead, but soon to their surprise Turtle was ahead. Coyote overtook Turtle, and then they began to laugh again. Soon they heard the Turtles cheering, and to their amazement Turtle was far in the lead. Again Coyote overtook Turtle, and again Turtle came up far in the lead. The Coyotes cheered one moment and the Turtles the next. Just as Coyote had passed Turtle and was near the goal, Turtle crossed the line, and all the Turtles set up a loud cheer. Coyote ran off in the grass, and is wondering yet how Turtle beat him in the race, and all the other Coyotes are angry at him because he lost the race and caused them to lose so many bets.

68. COYOTE, WILD-CAT, AND THE OLD WOMAN.

An old, blind woman lived all alone. Her home was far away, and no one ever came to see her and few people even passed by. Though she was blind and old she somehow always had plenty to eat and seemed to get along as well as any one else. She always had her pot full of meat, and those who passed could smell it cooking, and they wondered who brought the meat to her. Whenever she sat down to eat she would always say, "All ready for dinner," just as though she were calling some one to come and eat with her; then she would say, "Orphan, I was only talking to myself."

One day Wild-Cat happened to come to her house while he was out looking for something to eat. He smelled the cooking meat, and so decided to stop a while. When he went in he saw that the old woman was blind. He slipped quietly to a corner and sat with one eye on the boiling pot and the other on the old woman while he tried to make a plan to steal the meat. After a while the old woman took the pot off of the fire and sat down to eat, but first she called, "All ready for dinner. Orphan, I was only talking to myself." Wild-Cat sprang up ready to run, for he thought that she saw him and was talking to him. When she did not say anything more, but began to eat, he forgot his fright and slipped over and began to eat, too. He ate very quietly, being careful not to crack any bones or to make any noise in chewing or swallowing. He ate until there was only a little left in the pot; then he slipped quietly out. After that he came there every day and ate so much that he grew slick and fat.

One day Coyote met Wild-Cat and said: "You always seem to have plenty to eat, and yet I never see you kill any game. Where do you get so much to eat?" Wild-Cat told Coyote how he went to the old woman's home and ate from her pot every day. Coyote wanted to go along, and so Wild-Cat agreed to take him, but first he made him promise to keep very quiet and to do only what he was told. Coyote promised, and so they started to the old woman's place. When they came near Coyote smelled the cooking meat and started to run on ahead, but Wild-Cat pulled him back. They slipped inside and sat near the door while the meat was cooking. When the old woman took the pot off of the fire and called, "All ready for dinner," Coyote jumped up, and it was all Wild-Cat could do to hold him back. When the old woman began to eat, Wild-Cat and Coyote slipped up and quietly stole meat out of the pot. Coyote put a big piece in his mouth and began to chew so hard that he forgot all about keeping quiet. His jaw came down on a bone and it cracked so loud that the old woman jumped up. Wild-Cat saw his jaw coming down on the bone and was out of the house by the time the old woman jumped up. She ran to the door and closed it, and then took a long spear that stood in the corner and began to poke around in the room. Coyote slipped about for some time, but finally the spear pierced him and he cried out with pain. Then the old woman knew for sure that some one was in the house, and so she kept on poking until she killed him. Wild-Cat came back next day and found Coyote dead. He was sorry, not because he cared for Coyote, but because he was afraid to go in the old woman's house again to eat, for fear she would kill him.

69. COYOTE CHALLENGES THE SNAKE.*

One time while Coyote was out hunting something to eat he decided to go where Snake lived. He started in the direction he thought Snake lived and went to many places, but he could not find him. He went

* Told by Annie Wilson.

along talking to himself, saying, "I thought so; Snake is not so poisonous as people think, and if I ever find him I will show him my power." He kept going from place to place. Finally he came to one place and thought he would stop and rest for a while. He was not there very long when he heard some one calling him. He arose and looked around and saw Snake coming toward him. When Snake came up to him, Coyote asked him how he was getting along in the world, since he had been made so small. "You look so small that I do not think you can do very much harm to any one, though I have heard many times that you have much poison. They say that you are more dangerous than I, and so that is the reason I have gone from place to place looking for you. Now that I have met you I want you to show me in what way you are more powerful and dangerous than I am." Snake said: "Yes, I look very small to you, but you know that although I am small I am given power by our Father, and by his aid I have done many things in this world. I have killed many animals, large and small. Now you have come to see me, and whatever you want me to do I will do it; but first tell me what you want me to do." "Well," said Coyote, "I want to see which of us has the most power." "All right," said Snake, "you may bite me just once anywhere you like, and I will bite you, too, and in that way we will see who has the more power." "But you have to bite me first," said Coyote. "All right," said Snake, and went up to Coyote and bit him on the top of his nose, and then said: "That is all I can do." Coyote stood there as though he was not hurt at all. He asked Snake if that was all he could do, and Snake said: "That is the best I can do to show you my power." Coyote said: "Well, it is my time to show you my power." "Yes," said Snake, and so Coyote came up to Snake and bit him nearly in two. Snake cried out and begged Coyote to let him go. "Now," said Coyote to Snake, "you lie there and I will lie here. We will call to each other every now and then, so that we can see who will live the longer." Snake went a little way off and laid down, acting as though he were about to die. Coyote also went off a little way and lay down. He was thinking Snake would die in a little while, and so he called out to him. Coyote could just hear him answer in a weak voice, as though he was almost dead. After a while he heard Snake calling him and he answered with a big voice. They kept on calling to one another all night. Toward daylight Snake called Coyote, but no answer came from him. He called again, but still no answer. The third and fourth times he called, but there was no answer. Snake went over to see what was the matter, and when he got there he found Coyote all swollen and dead. Snake was more dangerous than Coyote.

70. COYOTE TURNS INTO A CORN MILL.*

The women made their corn mills from the trunk of an old tree. They cut a piece about two feet through and three or four feet high and hollowed it about twelve inches deep in one end. There they placed their corn and ground it to meal with a pounder. There were many of these mills, but one that was very old and smooth the women liked best.

One day a woman went to use the old corn mill, and as she pounded her corn she saw that it was diminishing too fast, and when she had it ground she saw that she had only a little. She gathered up her meal and said nothing, but watched the next woman pound her corn. It disappeared in the same way, and so did the corn of the third and the fourth women who came to use the mill. They all wondered what could be the matter with the mill, and they examined it carefully and saw that it was not the old mill that they had always used. One of the women cried out to get an axe and cut it and see where their corn had disappeared. As one of the women ran to get an axe the mill fell over and began to roll about, and Coyote jumped up from the place where the mill had been and ran away. Coyote had turned into a corn mill and hidden the old one so that he could get all he wanted to eat.

* Told by Wing.

ABSTRACTS.

1. THE CREATION AND EARLY MIGRATIONS.

In beginning darkness rules. Man comes, and soon there is village with thousands of people. Man disappears; returns with seeds. He says Sun is coming and will be given power by Great-Father-Above. Unknown man tells people to select chief. In council is Coyote, who tells people to call unknown man Moon, because he is first created man on earth. People make Moon chief, and he selects errand-man to summon people, and chief tells them they are to move to better world. They divide into groups and select leaders, and chief gives each leader drum and tells them to sing and beat their drums. None of them is to look back, lest they should be stopped and stay in darkness. People move westward and come out of ground to another world. Coyote tells chief world is too small, and looks back. Half go back and others go on west. Chief throws dirt in front of him and forms high mountains. People come to mountains and there make their first homes. Moon goes to mountain top and sees people have scattered in different directions. When together they spoke Caddo; now each group speaks different language. Moon says direction to right is north, or cold side; that to left south, or warm side. Sun comes up from east and goes down in west. He goes too fast to do any good, so Coyote starts eastward and tells Sun he wants to talk with him. They walk together slowly, and when half way to west Coyote tells Sun he is going to defecate and asks him to wait a while. Coyote goes behind bushes and then runs away. Sun waits; then starts on slowly, still waiting for Coyote. Beginning of real people was in village called Tall-Timber-on-Top-of-the-Hill. Moon calls people together first time in new world, and says child will soon be born of woman and will have more power than any one else. He will name himself Medicine-Screech-Owl, after former chief, and have with him bow and arrows. Child comes and has bow and arrows. On his first birthday he names himself Medicine-Screech-Owl. He says bow and arrows are for men to kill game. He teaches people to make bows and arrows. In those times animals talked to human beings and they understood one another. Afterward some human beings turned into animals. Medicine-Screech-Owl visits most ferocious animals in behalf of people. People have little to eat, except man and woman known as Buzzard, who have plenty of meat. Coyote, in order to find out where they get so much meat, turns into dog. Buzzards find little dog. Man says it is not real dog. To find out whether it is real dog, woman pinches its ear and it howls like dog. Man tells woman to give dog some meat to see whether it eats fast. She does so, and Coyote takes his time in eating it. So Buzzard believes woman and they keep dog. Coyote stays with them until meat gives out and then watches them. Buzzard starts out after more meat, leaving dog at home. He follows and finds out where they get their meat. Three days afterward he goes to cave with rock as door, where he had seen Buzzards at work. He opens place and out come thousands of buffalo. Buzzard discovers what has happened, but dog has gone. Coyote tells people to make bows and arrows, as buffalo are coming. Buzzards now have to look for dead meat; so they become real buzzards. As time passes on, people notice that Moon pays no attention to them and stays at home. He is unmarried and lives with his father and mother and one very young sister. Unknown to his father and mother, Moon goes by night to see his own sister. She does not know who he is; but one night she put black paint on her fingers, and when man comes she passes fingers across forehead and makes black marks. In morning she sees marks on his forehead. When Moon learns that people are finding out about him, he is ashamed and wishes to leave them. Father-Above takes him away and places him far above, where people can see his shame marks on his forehead. After Moon has gone, people select Medicine-Screech-Owl as chief. He makes them move westward, climbing mountains. At top they see large lake, and Medicine-Screech-Owl says waters are tears shed by Moon for wrongs he had done his people. People keep moving on westward and make bows and arrows. They go long distance to hunt buffalo and other animals. One place they dare not go to, as in water there is most ferocious animal. Medicine-Screech-Owl goes to kill animal. He makes narrow road through thicket and sees animal. He has bow and some corn to use in killing it. He throws corn into air and it becomes blackbirds, which fly over head of animal. When animal rises to draw blackbirds down, Medicine-Screech-Owl shoots it through heart, first from right, then from left side. Animal falls and dies. Coyote now becomes bad man and makes all kind of trouble among people. Medicine-Screech-Owl tells Coyote he must go, but on Coyote's saying he is going to stop his mean tricks, chief allows him to stay until he should be captured or killed at any time.

2. THE ORIGIN OF DAY AND NIGHT.

In beginning people live in darkness. They discuss how they can get light. Man who is prophet is appointed by Coyote to investigate. Prophet reports that there are yellow, black, spotted, half-spotted, and white deer. He says that if they kill both black and white deer they will have day and night. They hunt until they kill black and white deer, and from that time we have had day and night.

3. THE ORIGIN OF ANIMALS.

People and animals live together and are same in beginning. After a time there is not food for all. Council is held and chiefs determine that some shall become animals and be hunted for food. People living near burnt grass are rolled in ashes until they become bears. They are given ten lives. When killed first time, second life is to arise from blood spilled upon ground, and so on through other lives up to tenth, bear to become fiercer each life, and finally to eat human beings. People living near long grass are rolled and become buffalo. They are given ten lives and put to live upon prairie. Deer are made in same way, and after them all other animals.

4. COYOTE REGULATES LIFE AFTER DEATH.

Coyote proposes rule that when any one dies he shall be dead forever and no living person ever see him again. People are well pleased, and from that time when anybody dies he is gone forever. People are taken to sky and become stars. Morning-Star has three brothers, and he is leader. He gets up early now, because formerly he was errand-man and had to rise early. His brothers are Evening-Star, North-Star, and South-Star. They watch lest enemy should approach. Their father was Great-Star and was chief of people. They believe every one when he dies goes up to sky.

5. COYOTE AND THE ORIGIN OF DEATH.

In beginning there is no death, but there are so many people that there is no room for any more. Coyote thinks people should die for good, but all others decide that people shall come back. Medicine-Men build a grass lodge and tell people that when white and black eagle feather on top becomes bloody and falls over, they will know some one has died. Then Medicine-Men will sing and call spirit to grass house and they will restore it to life again. Sign shows that some one is dead. Medicine-Men sing, and in ten days whirlwind blows from west, circles about, and finally enters by east. From it appears handsome young men. People rejoice, except Coyote, who is displeased. After feather becomes bloody and falls, Coyote goes to grass house and sits near door with singers. When he hears whirlwind coming and it is about to enter, he shuts door. Spirit finding door closed whirls on by. Death forever was then introduced. Ever since then spirits of dead wander over earth until they find road to spirit land. Coyote runs away, and ever since he runs from one place to another, looking back to see if he is being pursued. He starves, as no one will give him food.

6. THE SECOND MAN WHO CAME OUT OF THE EARTH.

Moon first man to come out of earth into world. Second man is Tonin, who is greater than Moon and more powerful. He is four feet high and rides horse no bigger than dog. He can turn darkness into light and have anything he wishes for. By wishing he can go any distance, and he can kill any game by pointing his forefinger at it. From time to time he disappears into sky. He can foretell future. He calls people together and tells them about this world, and says in six days he is going away and will be gone six winters and seven summers. He wishes them to come and see him start. On sixth day Tonin sings death song, and is gradually lifted up from earth to sky. When it is time for him to return, stars become brighter and larger. When day comes and Tonin's brother gives sign that he is about to return, large stars come up in east and Tonin comes back to earth. He tells people about future, and that strange people will come and frighten away buffalo, deer, and bear. After some time he tells people he is going as before, but that he will not return. He goes up into sky.

7. SNAKE-WOMAN DISTRIBUTES SEEDS.

Great-Father gives seeds of all growing things to Snake-Woman. Afterward she and her two sons travel over world to carry seeds to people. They give six seeds of each kind of plant to every person. Snake-Woman says they are not to allow any one, especially children, to touch them or ever point to them as they grow. If any one gathers seeds too soon she will send poisonous snakes to bite them.

8. THE FLOOD.

Waters of earth dry up. People become crazed and cut to pieces dead animals that dwelt in water, thinking them responsible for water disappearing. They see man in sky coming from west. Wind blows and man lights on ground, carrying small green leaf. He tells people they have abused him and he is angry. He motions leaf in four directions and water falls from it. Waters grow in volume and rise all over world to highest mountains except one. To this mountain man leads few of people, and they stay four days. As waters rise man causes mountain to rise. When green things appear on earth again, he leads people down from mountain. They find many people have been turned into alligators and other water animals.

9. THE EFFEMINATE MAN WHO INTRODUCED STRIFE.

Man works and dresses like women and goes with them. War breaks out, and all men go to fight but this one. Old man threatens to kill him if he will not fight. Man refuses to go, and when old man threatens to have him killed by warriors on their return, he says they can not kill him and he will bewitch people and cause them to fight and kill one another. Old man incites warriors to kill man as coward, and they beat him until they think he is dead. He jumps up alive and they cut off his head. He runs about headless. People notice spot on little finger of left hand. They cut it out and man lies down and dies. Soon after, people begin to fight and quarrel and kill each other. Then old man tells people what coward had said, and they are sorry they killed him.

10. THE ORIGIN OF THE MEDICINE-MEN.

In days of old, people and animals are on friendly terms. Animals possess wonderful powers and give people power in dreams or visions. Man who has had dream remains several days in silence. He then calls friends and old men to lodge and teaches them his songs and dances. They all call themselves medicine-men, and if any one is sick they hold dance in grass lodge for six days and nights. First medicine-men to receive power and give dance are two young brothers. They are brave hunters. In sleep in lonely woods both have dream, in which they walk together toward east. They see man coming rapidly toward them. He stops and after long talk reveals bag and asks them choose any kind of medicine. He gives them medicine for long life and teaches them how to use it. When boys wake up, each remembers dream, but says nothing. After many months each begins to try his powers. War breaks out with Chickasaw and many are killed or taken prisoners. Chickasaw on way home have war dances and dance around prisoners. Young man escapes, and when Chickasaw come after him he crawls into hollow log. After they return he crawls out and goes home. Many men are away when Chickasaw make attack, among them two brothers with power. Men start to pursue Chickasaw and overtake them. At first sight they run into camp, kill many Chickasaw, and rescue prisoners. Strong-Wind and his brother exhibit wonderful powers. After many years brothers die and tribe has no medicine-man. Finally very young man is given powers by Black-Mountain-Bear. While out hunting, darkness comes and he lays down to sleep in shelter. He dreams that he is walking on narrow trail eastward and sees man sitting with head down. Man tells him he wants to give him medicine, and takes out many roots, of which boy is to choose six. He takes six roots, but old man tells him he must go before six men, who will explain their use. He gives back four. He sees old man sitting by trail, who explains use of his medicine. While going toward third man he awakes. He returns home and keeps silent. He wanders about, looking for roots seen in dream. At last he finds plant. Soon after man is about to die. Young man calls medicine-men together and teaches them dance song he has been taught in dream. They all go to sick man's lodge. They dance six days and nights before young man finds out what is matter with him. Finally young man begins to talk in strange tongue and dances slowly. He falls to ground and begins to crawl like mad bear. He places mouth on place where greatest pain is, draws pain out by blowing breath on place, and pain is gone. People know Black-Mountain-Bear has given him power. He is now called Black-Mountain-Bear-Medicine. Medicine-men's society holds dance and wants young man to show his powers. Sixth night he joins dance. He dances faster and faster and picks up gun. He takes out bullet and powder and puts them back again and gives gun to helper. He dances again, falls, kneels, and spreads out arms. Helper shoots him through breast and he falls in faint. He rises, dances again, and shows bullet to people. He has caught it in his hands. Another young man has wonderful power given him by Mountain-Bear. He has bear's skin that he causes to turn into young bear, which follows him about. Then he turns animal back into skin. There are two kinds of medicine-men. One has power to heal sick; another has power to prevent any one from being hurt or harmed. The latter are more powerful than others, as they can perform without medicine and can be with people afar off. They have a song of death which frightens away death. This power is generally given by Sun, Moon, Stars, Earth, or Storm, and also by some very wild and ferocious animals.

11. THE GIRL WHO MARRIED A TURTLE.

Girl lives with two brothers, who are famous hunters. Girl plays by water and gets to know Turtle. He asks to be her husband. She consents and sees him as often as she can. Brothers go away for many days. Girl builds high bed for Turtle; carries him home and puts him in it. Every day she puts bowl of potatoes in bed for him to eat. Brothers come home, and she wants to take Turtle back to river, but he begs to stay. Boys notice high bed, but suspect nothing until they see sister take bowl full of potatoes to bed and take it out empty. They pretend they are going hunting, and soon return. Girl goes to dig potatoes. Boys find Turtle in bed and kill him, and then run away. Girl finds husband dead and runs after them. Boys come to river, where many white ducks are playing. Boys offer to paint ducks different colors if they will carry them and bob-tailed dog across river. Ducks carry them across and soon girl comes. Ducks say they have not seen boys and dog. White duck, whom boys have forgotten to paint, says boys and dog have just passed. Duck carries girl across. Brothers see her coming. They meet three white doves, who, at their request, fly to the sky with them and dog. Smoke makes doves' white feathers gray. Girl asks doves where brother and dog are. They point to three bright stars in southern part of sky. Girl looks at stars and falls dead.

12. THE MAN AND THE DOG WHO BECAME STARS.

Man has dog who when they are off alone hunting talks as if he were man. He can always tell what is about to happen. Once Dog comes running back and tells master they are coming to dangerous place. Dog scents deer and starts on trail. Man shoots deer, which runs to lake and jumps into water. Dog jumps in and holds deer until man comes. They kill deer, and man swims toward shore with it on his shoulders. Dog cries out. They are surrounded by poisonous and dangerous water animals. Man prays to spirits to help them, and water leaps up and throws them on shore. Man in gratitude throws some of deer's flesh into water as sacrifice. Man and dog decide to leave this dangerous world and go to sky to live. They are two bright stars in south.

13. EVENING-STAR AND ORPHAN-STAR.

Poor orphan boy lives with large family who mistreat him. He goes with people to island in large lake to hunt eggs. They go away while he is asleep and leave him to starve. He lives for time on scraps he finds around dead camp fires.

He sits by water's edge and tries to catch fish as they swim past. Large animal with horns comes to him through water. He tells boy he will carry him to mainland. He climbs upon animal's back and animal says he is to tell him if he sees star. They have not gone far when boy says there is big star in west. Monster sees it, turns and swims back to island. For five days he starts with boy and swims back again because boy sees star, but each day he gets little farther. Sixth time he is within few feet of opposite shore when boy sees star. Boy says nothing and monster swims on until they are near shallow water. Boy sees great black cloud roll in front of star. He jumps off animal's back and swims to shore. Something strikes animal with awful crash and he is killed. Handsome young man comes and thanks boy for what he has done. He has long tried to kill monster, because he made waters of lake dangerous. Man, who is Evening-Star, takes boy to sky and he stands near him as Orphan-Star.

14. THE GIRL WHO MARRIED A STAR.

Maiden sleeps in arbor and watches stars. She goes to sleep, wishing one star especially would marry her. When she awakes she sees old man sitting by fireside. He tells her she is Star's wife. She begins to cry. Star's sister is preparing food, and tells her to stop crying and come and eat. Women go out to dig potatoes. Big potato is gate of heaven and covers entrance to world beneath. Girl tells Star's sister she wants to go back again. Sister tells Star and he agrees to let her return in six days. They begin to make rope of young elm bark. In six days rope only half long enough. It is finished on eleventh day. Next morning girl is fastened to end of rope and let through hole. Rope is gradually slipped out, and after long while she sees earth. She travels many summers and winters. Her food is almost gone and she is far from earth. Rope ceases to slip and she hangs there long time. She sees Buzzard circling around below her and she calls to him. He takes her on his back and flies until he nearly gives out. Hawk helps him and flies with girl until he gives out. Buzzard takes her again and alights with her near village. Girl is weak and exhausted, and woman helps her to lodge. Mother does not know her at first. After tenth day people come to tipi to see her. She tells them her story, and especially about kindness of Buzzard. After that, people always leave one buffalo for buzzards after big killing.

15. THE GIRL WHO MARRIED A STAR.

Very beautiful girl, whose three sisters marry, will not receive attention. She is tired of home and prays spirits to help her go wherever she wishes. She watches stars and wishes she may become wife of North Star. She sees very old man sitting by fireside and thinks she is dreaming. Old man tells her she is in his home as his wife, as she wished. She does not like looks of old man, but has to stay. She tries to get away and thinks of big stone North Star has told her not to move. She goes and lifts stone and finds she can look down to earth. She wonders how she can get down, and thinks of rope of soapweeds. When North tar is out at night she cuts soapweeds, and when she has enough she begins to make rope. When rope finished she fastens it to rock, and next time man goes away she climbs down. She comes to end of rope before she comes to tree tops. She hears noise, and bird passes under her feet. When passing fourth time he tells her to step on his back and he will take her home. She gets on bird's back and he flies with her to her home. Before leaving her he says he is Black-Eagle.

16. LIGHTNING AND THE PEOPLE.

Lightning lives upon earth with people, but he becomes so powerful and kills so many people that he is sent away. Great monster lives under ground and begins to carry away people. They can not kill him, as he always disappears under ground. Lightning tells them he will kill monster if they will let him come back. He will kill all monsters and make earth safe place for people to live. People let Lightning come back.

17. THE BROTHERS WHO BECAME LIGHTNING AND THUNDER.

Medicine-Man has wife and child twelve years old. He kills many deer. One day on returning from hunting he finds boy alone. He asks where mother is, and child says she took water bucket and went toward creek. They go and can not find her. There are footprints at edge of water, and man knows something has taken his wife. They go back to house and mourn for six days. Seventh day Medicine-Man goes hunting. While he is gone, boy plays with bow and arrows. Fourth time father goes, and while boy is playing, unknown boy with long nose and very long hair comes. He says he is boy's elder brother, and will always come to see him when father goes hunting, but he is not to tell father. They play with bows and arrows, and unknown boy runs back to woods when he sees Medicine-Man coming. Medicine-Man again goes to hunt, and after fourth time boy wakes father at midnight and tells him about his brother. Father says they must capture boy and tells son he must play as though he had gone away, and he will turn into small insect and stay behind door. Boy comes, but sees man behind door and runs away. Next day father places himself at edge of roof of grass house, but boy again sees. Third day father tells boy to tie other boy's hair, and then places himself in middle of fire, but unknown boy finds him out and runs back to woods. Next day man goes behind another door, and fifth time he places himself in air, but boy each time finds him. Sixth time boy does not see which way father goes, and when he says father has gone hunting, other boy believes him and sits down by him. Little boy gets hold of his hair and says there is something in it. Boy tells him to get it out, and little boy ties hair as father had said. He calls and father jumps out of grass house. They capture boy and keep him in grass house six days. Then they wash boy, and Medicine-Man cuts his nose off and makes it look human. Before going hunting again, Medicine-Man tells boys not to go to place where large squirrels live, for they kill little children. They go to place and big squirrel comes out of hole in tree, sticks tongue out like snake, and takes young brother into tree. Other boy goes home and brings fire. He puts hard red stones into fire, and when hot throws two stones into hole. Large squirrel comes out and drops on ground dead. Boy goes and cuts open squirrel's stomach and finds brother alive. Boys go to make arrows. Unknown boy makes two arrows for his brother and paints one black and other blue. They make small wheel of thin bark. They roll wheel to each other and shoot it with arrows. They play with wheel every day until Medicine-Man's boy misses it and wheel keeps rolling and they can not find it. They start out after wheel, and when they have gone long way, they stop for rest. They pray to spirits to help them. Unknown boy puts pecan nut in ground. It sprouts and tree grows up to sky. Boy tells brother he is going up tree, and will be gone until he has dropped all bones in his body and his head, and that brother must gather bones in pile, cover with buffalo calf's hide, and shoot arrow up as hard as he can. When he hears arrow coming he is to tell him to get out of way, and bones will do so. Boy then climbs tree, and after a while his bones drop, and little boy piles them together as he was told, and shoots black arrow, and brother jumps from calf hide. He says his father has given him very dangerous power, and that brother must climb tree to get power. Little boy climbs tree with like result. Little boy has power of thunder and other boy power of lightning. They go on until they come to large lake and see place where wheel has passed into water. They pray again, and boy plants another pecan, and large tree springs up and it bends over lake and makes a bridge. They cross and find trace of wheel. They follow it and see old man. Lightning boy tells Thunder boy that old man took wheel and has it in his right side. They kill man and find wheel. They go on and find old man's people, whom they kill. They come to pile of bones and they are bones of Medicine-Man's wife. They cover them with buffalo calf hide, and bring her to life again by means of black arrow. They all start for home. Lightning boy gets there first and finds father very old man and still weeping for his children. He goes out to meet his wife and son. All live happily for number of years, and then father and mother die. Boys are lonely and decide to leave world. They go up in sky, and when clouds gather in storm, Lightning and Thunder are seen in their midst.

18. SPLINTER FOOT BOY.

Orphan boy who lives with grandmother is famous hunter. While long way from home stick pierces his leg and breaks off inside. Leg swells and friends have to carry him home. Leg continues to swell and finally skin breaks and child comes. Boy is angry, but grandmother cares for baby. While she is away boy takes child to lake and leaves it. Child lays there until it grows to be good-sized boy. Many birds fly over lake, and when they are half way cross, lake leaps up and draws them down. Boy sees this, and one day sees big water monster in water. He wishes he could kill water monster, and while thinking about it some one hits him on back. He turns, and there is Medicine-Screech-Owl, boy about his own age. Medicine-Screech-Owl says he will help him to kill monster, and tells him to go to grandmother's and get six arrows, bow, and six grains from six different kinds of corn. Grandmother surprised to see him and gives him all he asks for. He returns to lake and Medicine-Screech-Owl throws three grains of each kind of corn into air. They become birds and fly across water. Water monster leaps up to draw them down, and boy shoots at monster. Sixth arrow pierces it through and it rolls over and floats on water. Medicine-Screech-Owl says it is largest water monster in world. He takes bow and pulls monster to bank. He disappears and boy goes to grandmother's house and tells her what they have done. Boy goes again to lake. Water is very low, and so clear he sees fish swimming about. He dives to catch fish, and sword-fish goes right through him. Boy shoots fish with bow and arrow. Next day all water gone, but boy sees two large shells. He takes them home and cuts them so that he can put them over holes made by sword-fish. He wears one in front and one behind. Shells have power of hearing any sound in whole world. Whenever boy wants to hear anything he puts shells to his ears. He now becomes great medicine-man, and people plan to kill him. He and grandmother go to top of high mountain near village and make grass house there. He places two fierce dogs at door to guard house. Boy knows people who are planning to kill him by means of his shells. They die one after another, and people suspect boy is bewitching them. Many warriors try to steal to his home to kill him, but he hears them coming and sets dogs on them. Finally, Medicine-Screech-Owl decides to interfere. He starts up trail to boy's house, and blows so hard that it takes magic power of sound from shells. Near top of mountain he blows breath again, and dogs roll over asleep. He passes dogs and blows again, and old woman falls asleep. He does same with boy. He enters house and takes shells off boy, walks around, and then goes away. When almost down mountain he blows breath and boy wakes up. He misses shells and begins to look for them. Grandmother will not wake up and he shakes Medicine-Screech-Owl's breath out of her. Dogs will not wake and he knocks breath out of them with club. Dogs wake up and scent Medicine-Screech-Owl's tracks. They start after him and come to big circle of fire. In midst stands Medicine-Screech-Owl wearing shells. They can not get through fire, and return without shells. Medicine-Screech-Owl keeps them some time, and then takes them back to boy and makes him promise not to bewitch people any more.

19. MEDICINE-SCREECH-OWL.

On Medicine-Screech-Owl's first birthday he is given bow and arrows. He names himself Medicine-Screech-Owl and will not have any other name, although there is ex-chief by that name. Ex-chief hears that child's name is same as his, and says he will kill boy if he does not do what he tells him. He sends for boy and gives him watermelon seed and tells him to plant it that evening and in morning to bring him big watermelon to eat. Boy takes seeds and throws them on ground near his lodge. Watermelon plant springs up and in morning many large watermelons are on it. Boy takes melon to ex-chief, who is surprised and determines to destroy boy. Ex-chief again sends for boy and tells him to take large bull to his house and bring milk the next morning. Boy takes bull and in morning goes near to ex-chief's lodge to chop wood. Ex-chief sees him and asks him if he has already milked bull. Boy says he has not, but is in hurry to cut some wood, as his father is going to have child. When ex-chief asks if he has ever seen man have child, boy asks him if he has seen bull give milk. Third time ex-chief sends for boy, saying he and some friends are going to have fine time. They dig very deep hole and cover it with buffalo robe. Boy is told to sit on hide, and he goes down into hole, which ex-chief fills with stones and dirt until he supposes boy is dead. Man tells ex-chief that boy is still living, and ex-chief sends for him fourth time. He tells boy to go and sit down in middle of big fire. Boy does so and sits until fire burns out. He then arises unharmed. Boy makes big fire and tells ex-chief it is his turn to go into fire to show whether he has any power. Ex-chief goes in and is burned to death. Boy now goes from place to place, although mother knows that people envious of his power would try to kill him. He hears three men talking about him and determines to visit them. They welcome him and ask him to go into lodge. He goes in first and then stands near door, which is very small, and kills the three men as they enter, one at a time. He hears of Snow-and-Cold, who lives far away in the north and whose visitors, if they stay over night, are frozen before morning. He starts to visit him and sails over lake on eagle feather he wears on his head. Geese on other side of water make noise, when any one crosses, to warn Snow-and-Cold's people. They do not see Medicine-Screech-Owl, who goes to Snow-and-Cold's lodge and finds him asleep. Medicine-Screech-Owl speaks and Snow-and-Cold looks around, but can see no one. Finally, boy shows himself and tells Snow-and-Cold he has heard so much of that place he has come on visit. In evening

Snow-and-Cold tells boy to sleep on bed of snow. He watches boy and sees light near his head. Boy has feather sticking straight up on pillow. Snow-and-Cold arises and punches snow in place that seems like fireplace with cane, and fire springs out. When he has warmed himself he covers fire and goes back to bed. Soon boy does same thing. In morning Snow-and-Cold calls to boy to get up. He thinks boy has been frozen to death, but he jumps up and says he has had fine sleep. After talking to Snow-and-Cold, boy goes back home.

20. MEDICINE-SCREECH-OWL.

Beautiful girl, who had no male acquaintance, becomes pregnant. She can not explain it. She goes with other girls to dig potatoes, but can never find any. She hears voice cry, "Mother," and it is that of child in womb. It tells her where to dig and she finds many large potatoes. Child is born, and at his own request is called Medicine-Screech-Owl. Child grows rapidly, plays with other children and goes to watch them fish. He tries and catches big fish. Soon he acquires fame as a fisherman. Persons begin to fear him, and employ powerful medicine-man to kill him. One day while fishing he sees reflection of big cloud in water and knows medicine-man's intention to send Thunder to try to kill him. He walks into water, and when Thunder and Lightning come he raises bow over his head and Lightning rolls into water. This occurs again and again, and medicine-man, realizing that boy has more power over Thunder than he has, gives up. Long afterward, while resting in lodge, boy thinks something is going to happen to him. He gets his bow and arrows, lays on bed, and sings. Soon he hears great noise and he knows that medicine-man is sending cannibal monster to destroy him. He hears its roar and feels its hot breath and it leaps on his tipi and falls through. Then he arises and kills it. Afterward Medicine-Screech-Owl goes from place to place killing monsters and ferocious animals and healing sick. Where he is, death can not come. He heals sick by touch of his hand. Finally he tells people he is going to leave them, and disappears.

21. THE ORPHAN BOY WHO BECAME A WRESTLER.

Boy lives with old grandfather, who dies before he can teach boy to hunt. Boy begs from lodge to lodge, and at night returns to his lodge and cries. Boys come and tease him. He is brave, and when larger he makes bows and arrows and goes to hunt small game and has no longer to beg. When in timber he hears voice calling him. Strange boy comes and they play together. They try to see which is stronger, and orphan boy easily throws stranger. Orphan boy can not understand it. Strange boy says he is strong man and has given boy his power; that he is now one of strongest men in world. Stranger disappears and next morning boy starts to hunt. He kills three deer and starts home with them. Load is heavy and he can not go fast. At night he hears voice and sees stranger again. He goes with stranger to place where his friends meet to wrestle. He wrestles and throws every one. They fear him and leave him with stranger. Strong man tells boy how to use his power and then disappears. Boy returns home and soon afterward boys have wrestling match. Young man calls him to come into ring. At first he declines. On second call he runs into ring and soon throws man and kills him. Others are afraid of his strength. People hear of his deeds, and soon he has respect and fear of all.

22. THE DANGEROUS WATER MONSTER.

Man goes to creek to get water. He sees large animal like snake. It is moving slowly, and man runs two miles up creek before he comes to its head. He goes home and tells grandfather. He calls people together and tells them. They wonder whether it is good or evil omen. Old and blind man is sent for, and after a while he says sign is very bad, as it signifies waters will rise. Soon waters rise and form large lake. Lake is very dangerous. When crossing it no word must be said. Four men hunt on other side of lake. They start back and cross lake without making any noise. When near opposite shore one man, to try it, talks very loud. Lake rises and drowns all men but one who warned man not to talk. He calls others and they search for bodies. Two are found, but body of man who made noise can not be found.

23. SLAYING THE MONSTERS BY FIRE.

In olden times world was full of wild animals who ate people. Coyote calls council to see what can be done with them. It is decided to set fire to grass and burn wild animals and everything on earth. White-Headed-Hawk and Crow are sent to Star to say that people are coming to his house to live. Star says there is room for people if they can get up there. Long rope of soapweed is made, and White-Headed-Hawk and Crow fly up with it and give end to Star, who puts end under big stone. Rope is so long it reaches to earth. Gray and Black Snakes carry fire over world. When fire comes near, people begin to climb rope. Then wild animals come and begin to climb up. Bat is sent to cut rope just above wild animals. Bat chews rope and rope breaks, letting all wild animals down. Many are killed. Bat goes down and sees immense animal on ground, and all others crawling into it to escape fire. Bat pulls hairs out of animal's nose. Animal sneezes and blows all other animals out and they burn to death. Bat tells people all bad wild animals are killed, and they come down rope again.

24. SLAYING THE MONSTERS BY FIRE.

In beginning some animals live with human beings and are friendly ; others are strong and dangerous. Grass is taller than trees are now, and wild animals prowl through it. Morning-Star in council of people says only way to kill all dangerous animals is to burn grass all over world. Fire is man to do work, and Morning-Star appoints two men to assist him, Black-Snake, the fastest runner in the world, and Skunk, the slowest. Fire puts fire on end of Black-Snake's tail and between toes of Skunk's hind foot. They start in east, one going north, other south, to meet in west. People make rope of soapweeds to reach the sky. Pigeon goes up into sky to see when fire approaches. When rope finished, Crow takes rope and fastens it firmly to sky. As fire approaches, people begin to climb up rope. Bad animals get hold of rope and it moves upward. People send Bat, who has sharp teeth, to cut rope. Finally it breaks and lets bad animals fall down. Bat follows and sees animal so large he has room for all bad animals. These go in and Bat follows. He pulls hair from animal's nose. It sneezes and throws all animals out through nose. Animals are burned. Bat flies up to people, but is scorched, becoming yellowish. People return to world again, and ever since it has been good place to live upon.

25. HOW THE BUFFALO CEASED TO EAT HUMAN BEINGS.

At first Buffalo ate human beings. They were many-colored and were so numerous that men dared not go on plain alone. Buzzard is only man who has power to go in midst of them and kill them without being hurt. Other people live in villages and hunt together. Some men hunting turkey and deer, while crossing prairie, see black cloud coming and know it is great herd of Buffalo sweeping down upon them. They throw away everything and, running very fast, take refuge in dense thicket. People now take courage and venture farther from home. Four men go to hunt bear. They trail bear. It runs into open plain and men kill it there. They hear noise like thunder and see Buffalo upon them. Buffalo catch all but one man, who gains timber and climbs tall tree. Buffalo try to butt it down, but can not do so. At night man climbs down and runs home. People hasten to place where companions killed, but find only few bones scattered about. Buffalo eat many people until Coyote comes. Then people go into another country. Coyote is last to go through gate, and shuts it, so no dangerous animals can enter. He lets through only few Buffalo who have not tasted human flesh and so are not dangerous.

26. THE GIRL WHO HAD POWER TO CALL THE BUFFALO.

Girl who has power to call Buffalo lives with six brothers. They are stars, and every night leave girl to travel through sky. In morning they put girl in swing hung from sky and swing her through air. Buffalo see her and come, and boys kill all they want. Coyote comes to live with them. Boys tell him to stay, but make him promise never to try to swing girl. One day while all brothers gone Coyote makes girl get into swing and he pushes her. Buffalo do not come, and he pushes her higher and higher, until she disappears. Coyote tells brothers monster has carried her off. They drive him away and tell him he and his children shall always be hungry. They decide to go to sky and live with their sister.

27. THE OLD WOMAN WHO KEPT ALL THE PECANS.

Old woman is mother of pecan trees. She gives few pecans to people who go to lodge, but will not let them take any away. People are very hungry and decide something must be done. Old man has four little sons who are very troublesome. People are field rats and they chose four boys to go to old woman's to steal some nuts. One goes to see if old woman is asleep. When she goes to bed and snores he goes back home to tell brothers. Then he sees Coyote, who tells rats not to trouble about stealing pecans, as next day he will kill old woman. In morning Coyote goes to see her, and as she is getting him some pecans, Coyote strikes her on head with stone knife and kills her. Old woman dies, and ever since pecan trees grow everywhere.

28. COWARD, THE SON OF THE MOON.

When people first come out of earth, little boy is taken out by grandparents who are poor. Boy is fed by other boys and grows rapidly. He becomes successful hunter. His grandparents die and boy wanders away into timber to mourn. Man comes and embraces him. He is Moon, and says he will be boy's father, watch over him, and give him power. Boy goes home and weeps no more. Girl comes and asks to become his wife, and they live together. Wife sees husband has great power. Woman asks him to watch her child, who is asleep, while she goes to get water. When she has gone he wakes child up and cuts its leg off. When she returns child is dead, and young man is playing with leg. She calls people, and they come and kill young man. He comes out of grave and looks just the same as before he was killed. All men go on war-path except Coward, as people call him. When asked by chief why he does not go, he takes war club and goes out to fight. Arrows fly off from him and enemies see he can not be killed. Men run, and he kills many with war clubs. Next day he is sick, and vomits all arrow-heads that have pierced his body. He bathes and is well. Many years after he tells people Moon is his father. Then he arises and goes up to Moon.

29. THE FIRST WAR PARTY.

When people came into world they were divided into groups, and each group was given different name. Tribes began to fight each other, and Caddo fought Kiowa and Comanche. Caddo gather in council and chief sends errand-man to call all young men. Chief asks all who want to fight other tribes to sit in circle. Chief lays large buffalo hide in center of circle. He gives each man stick, and they beat hide with sticks and sing war song. They sing until Morning-Star drives other stars away. Chief and assistants go ahead to choose good place near water for camp. At dawn men march out, continuing war song, to place where they wait until noon, so that others who decide late may join party. While they are eating, chief makes speech, giving them rules for their conduct. They march by day and camp at night, chief in advance. When near enemy's country chief appoints four men as spies to go in all directions. They go on until they find enemy, and fight them, but scalp only one to show they have been victorious. When battle is over warriors leave and do as they please. Word is sent home, and people deck themselves with paint and feathers and go to meet war party. Scalp is put on pole and young men race for it. When they arrive at home all join in war dance.

30. THE POWER OF THE CYCLONE.

As boy sits on bank of river resting after his morning bath, voice speaks to him. He sees nothing, but, after gazing into water for long time, he sees man slowly rising to surface. Man comes and tells him to dive into water four times and to always face west. He does so, and man says he is power of Cyclone, but is growing old and his strength is going, and he has come to give boy his power. He tells boy to swing his arms about. He swings his arms and black cloud rolls up, and as he throws his arms farther, wind breaks from cloud and passes through forest, tearing up trees by roots and tossing waters in fury. At last man tells him to stand still, and boy drops his arms breathless and panting with exertion. Man tells him he has received power which he is to exercise only in spring, and calls him "Path-of-the-Cyclone." Then man disappears. Years after people see boy carried through air to sky on cyclone.

31. HOW THE CANNIBAL WAS DESTROYED.

Three men out hunting come to large tree on which something has been climbing. Near the base is large hole. Thinking bear is in hole, they thrust into it bundle of burning leaves and grass. Finally strange animal peeps from hole, and it is cannibal. Men run, and cannibal scents their tracks and follows them.

He overtakes one man, kills him, and carries him back to tree. He returns and overtakes second man, whom he kills and carries back. Third man is almost overtaken, but Mountain-Lion lies in wait for cannibal, seizes him by throat, and kills him. When man gets home he tells people what has happened. Cannibal's body is eaten by white and black wolves, and when people go they find nothing but his bones. They go to tree where cannibal lived, cut it down, and find two bodies, which they bury.

32. THE YOUNG MEN AND THE CANNIBALS.

Ten boys live with grandmother. Oldest goes hunting and does not return. Next day one of his brothers goes to look for him. He does not return, and next brother goes in search of him, and so on until ninth boy goes, leaving little brother at home with grandmother. At last youngest boy goes in search of brothers, putting eagle feather in his hair. After looking far, boy sees tipi and hears voice referring to him as meat. Old man comes out and asks if he is looking for his brothers. He says he will put him on path to find them, but boy must first do some work for him. He tells boy to put log on fire. He is to have four trials, and if he fails he is to lie on log and let man lift it. Boy can not move log, and lays down on it. Old man is about to spear him with iron nose of mask he wears, when unseen power pulls boy off log, and iron nose catches in log and holds man fast. Voice tells boy to take pounder from woman who is pounding corn and beat old man to death. Boy obeys, and, when old man dead, voice tells him to gather up his brothers' bones and put them in nine piles. Strange man appears and helps him, and then tells him to put his robe over bones, shoot arrow up in sky, and tell brothers to look out lest arrow hits them. Boy does so, and brothers jump out from under robe. Man tells them to burn tipi with man and his wife and scatter ashes. Man then says he is Sun and has helped them to destroy cannibals. Then he disappears. They return home to grandmother and tell story. People then know that Sun is their friend and willing to help them.

33. COYOTE AND THE SIX BROTHERS.

Old woman has seven sons. They are good hunters. One day oldest son goes to hunt and does not return. Several days after, his dogs come back, but he does not. This happens to six sons in turn. Mother will not let youngest son go. Long time afterward he sees Raccoon in tree. He chases it, and it leads him far into timber. It runs down hollow tree, and he climbs tree to get it out. Old woman tells him to throw Raccoon down, and she and his dogs will kill it. He throws Raccoon down and she kills it and one of dogs. Then she says there is another Raccoon in tree. He pulls it out and throws it down. She kills it and another of his dogs. This happens until he has pulled six Raccoons out of tree. As boy is about to pull seventh Raccoon out, it tells him to throw it as far as he can. While old woman is chasing him, boy is to run home as fast as possible, as old woman is witch and has killed all his brothers. He does so. When old woman finds boy is gone she starts after him, but can not catch him. That night boy dreams that he meets Coyote, who tells him his brothers are not dead, but are working for bad people and will soon die if they do not get away. Coyote promises to help him to rescue them. Next day he meets man, who tells him something. Man goes on and meets Flying-Squirrel, who is one of bad people's slaves. Coyote asks him about six brothers and hears they are slaves. Coyote says he would like to help them, and Flying-Squirrel suggests that wicked chief be killed. Flying-Squirrel carries Coyote across river hanging to his tail. Coyote lets go of tail and falls into river. He hides until he thinks of plan. Then he turns into corn mill and floats out on water. Woman persuades chief to get it, although he is suspicious. Woman uses mill, but one day all corn is sour. She tells chief, who says mill is Coyote. Chief has it placed on big log to spear it with his long, spiked nose. His nose sticks in log and corn mill turns into Coyote. Coyote knows chief and tells slaves to kill him. Slaves are free and brothers return home. Afterward when killing game they leave some for Coyote.

34. THE DEATH OF THE CANNIBALS.

People of village Tall-Timber-on-Top-of-Hill decide to move to another. Young woman whose husband is dead gives birth to baby and has to stay until she can carry child. She remains in deserted village many days. One night she hears some one outside and strange voice begs admission. She lets man in and he says he is Spotted-Wolf. He says he has come to beg her not to start on journey too soon, for there are many dangerous animals in way. She says she is lonely and wants to go to her people. Spotted-Wolf then gives her some tobacco and tells her if she meets danger and needs help to throw some of it to four directions and call to him; then he will come and help her. After few days woman starts with baby on her back. After traveling three days she sees in her way cannibal. She is much frightened and takes tobacco and throws it to four directions, praying that Spotted-Wolf would come. Soon big spotted wolves come from four directions and kill cannibal. Wolf from south conducts woman and child safely to her people. Another kind of cannibal lives as human being and eats dead people. They pretend to be sick when they hear of one who is about to die, and when he dies they pretend to die and are buried. In night they jump out of graves and steal dead person before spirits can take him away. An old medicine-man watches one of these beings for long time. Then he pretends to be very sick and spreads news that he is about to die. Soon he hears that watched person is sick, and then he pretends to die, first telling his sons to put bow and arrows in his grave and not to put much earth over him when buried. Person pretends to die also and is buried. At night he jumps out of grave and goes to get medicine-man. Medicine-man hears him and jumps out of his grave and shoots an arrow through cannibal and kills him. Ever since bows and arrows are put in graves with dead, that they may shoot cannibal.

35. THE MAN WHO MADE ARROWS FOR GHOST.

Two men hunt all day without finding anything. They stay in timber to hunt next day and go to sleep. They are awakened by voice whooping. One man is frightened and runs away. Other man stays, and soon dead person comes and asks if he can help him get into spirit land. He wants bow-string and two arrows. Man makes arrows and puts new string on bow. Dead person shoots arrows and goes up with them. He whoops to let man know that arrows have carried him up all right. Ever since bows and arrows are always made and buried with dead, that they may go to spirit land at once.

36. THE LAZY BOYS WHO BECAME THE PLEIADES.

In beginning of world lives old woman with seven sons. They are full of fun and play all day long. They will not work, and eat only in morning and evening. Mother scolds them, and one evening will not give them anything to eat. Boys are angry, and next morning they go to playground and go around and around house, praying to Spirits to help them. With every round they rise higher and higher in air, and at last go up to sky, where they are "The Pleiades." These stars are seen during winter, but at beginning of spring, at work time, they are gone.

37. THE LOST TIMBER SPIRITS.

When world is new, Coyote decides that people dying return to earth after ten days. Finally he makes rule that if anybody dies and is buried within six days he shall stay under ground. If not buried by seventh day he may escape. If caught he is to be brought home. Fire is to be kindled all around him, and after being kept at home six days and nights he is to be washed by some old woman and he becomes real person again. At death body is laid in hole, head toward east and feet toward west. Fire is made at feet and kept up six days and nights. If fire goes out grave is found open and tracks seen toward east. When they follow tracks and overtake dead person, fire is built all around him until he tries to escape sparks. He is then coming to life again and is taken home, and in evening of sixth day bathed and will then live again. When dead person not caught he becomes like large monkey and lives in the thickets. These monkeys talk to people and they are thought to be crazy. When people meet them they always ask for wrestling match. They are still living, but do not talk as they did when world was new.

38. THE MAN WHO TURNED INTO A SNAKE.

Two boys go hunting. One of them kills snake and eats snake meat instead of buffalo. He turns into snake and tells friend to find hole for him to live in. Friend carries snake to hole. Snake tells him that when people go to hunt they are to offer presents to him and he will help them. Snake lives there many years until lightning kills him.

39. THE WOMAN WHO TURNED INTO A SNAKE.

Man has wife and dog. At that time animals talk, and dog talks to man and woman. Every day man goes to hunt, and as soon as he has gone woman goes out and does not return until evening. Dog tells husband, and he says dog is to follow woman next time. Dog does so and sees woman go to large tree and whistle three times. Third time big snake comes from large hole in tree, goes to woman, and coils round her body. Finally it goes back to hole. Dog tells man, and next day he makes many arrows and tells wife that he and dog are going fishing. Instead of fishing they go to place where snake is. Man whistles three times and snake creeps out. When it reaches ground man shoots and kills it. He then cuts it into very small pieces to look like pieces of fish. They go to river and catch few small fish. Man tells wife he is going to cook fish and she is to go in grass house. Man cooks fish and snake flesh. He then takes snake flesh to wife for her dinner. He and dog eat fish. Man sends dog to see what wife is doing and he sees she is eating snake. Second time dog sees she is scratching herself all over. When she scratches, skin turns color of snake skin, until finally she turns into snake. She creeps away from grass lodge and goes to find snake. Some time after, when out hunting, man hears voice inside large tree and large snake comes out of tree. He knows it is his wife, but he passes on.

40. THE GIRLS WHO WANTED TO MARRY THE CHIEF.

Two twin daughters hear of chief in another village and obtain parents' consent to go and offer themselves in marriage to him. They start in search of chief's village. They meet man with turkey and tell him. He says he is chief, and is willing, but asks them to wait until he runs home and tells his grandmother. Man is Owl. He runs home and tells grandmother to clean up lodge, as he is bringing home two girls on whom he is playing joke. In morning she is to ask which turkey she is to cook, that girls may think there are many turkeys and good things to eat. Owl goes for girls, who are pleased with things, and marry Owl. Every day he comes in with turkey; as he goes to council and chief gives him turkey for allowing him to sit on his back. Finally twins grow weary of turkey and begin to suspect. They follow Owl and peep through opening in grass lodge and see Owl sitting in middle with chief on his head. Girls scream. Owl recognizes their voices, jumps up, throwing chief off his head, and runs home. He scolds grandmother for letting girls follow him, and they slip off and return home. Owl, angry at being fooled by his own joke, tells grandmother they must kill people. They gather all water by digging big hole and draining waters out from all rivers, springs, and lakes. Water is all gone, and people are dying of thirst, while Owl is splashing about in big hole. Every one goes in search of water. Crow, who was snow white then, comes to field where grass is all withered and big grasshoppers are jumping about. He runs after them, and makes so much noise that people think he has found water. They run in great haste, and are so angry with Crow for fooling them that Coyote rolls him in black earth until he is black. Coyote makes rule that if any one makes loud noise and arouses people's expectations he must either lead them to water or take hard whipping. Turtle falls in great crack in dried mud and halloos for help. People run, thinking he has found water, and Coyote takes him out of crack and gives him so hard a whipping that his shell cracks. Turtles still bear marks of cracks on their shells. Some one hears big splashing noise. He goes on and comes to hole where Owl sits playing in water. He tells people, and they consider how they can get water from Owl. Flea goes to Owl's lodge and enters as his grandmother is about to take bath. She has big jar full of water in front of her. Flea crawls up her leg and bites her. She gives big kick and upsets jar. When Owl sees water running in all directions he opens eyes wide in astonishment, and they have been that way ever since. All people are grateful to Flea. Coyote puts him on his back that he may have warm home.

41. THE POOR HUNTER AND THE ALLIGATOR POWER.

Hunters go on two months' hunt and take their wives with them. Among them are a poor man and wife who are starving. Poor man hunts day after day, but returns without anything. One day, after hunting all morning, he hears some one calling him. He goes and sees person who wants to find water. When hunter tells him there is water short distance off, unknown person asks man to carry him. He does so, and when they reach water person tells hunter to take off clothes and to get on his back. Man shuts eyes, and when he opens them he sees heads of all kinds of animals. Unknown person tells man to point out heads of animals he wants to kill. He does so, and person, who is called Alligator, gives him powers, and when he is again on dry land tells him to go hunting. He kills four big deer, dresses them, and goes to camp. He takes his wife, with two horses, and finds deer, which he puts on horses. Everybody wonders when they see horses loaded with meat. After that, man never fails to bring back much meat when out hunting. When people start back home, they find that man they had made fun of is most successful of all hunters. They name him Deer-Head, because of his bravery in killing big deer. After many years he disappears, and his younger brother says some one came during night and took him away home. Long time afterward hunter shoots large deer, which walks very slowly, and after going over hill calls to him to come on. Man starts back home and people think Deer-Head has changed into deer.

42. THE BOY WHO MARRIED A MOUNTAIN-LION.

Little boy tells parents he is Red-Mountain-Lion, and they so call him. He becomes a successful hunter. Once he acts queerly when he returns from hunt, and next time brother follows him. He tracks him to mountain cave, where he sees brother with female mountain-lion. When Red-Mountain-Lion comes home he acts stranger than ever. Hearing some one talking about going to kill mountain-lion in cave, he starts off alone to hunt. When men come to cave they see footprints of man and mountain-lion leading away from it. Man does not return to his people, but years afterward he is captured by hunting party and is carried home, where he stays. He and brother form war party, and he goes off to get power. He finds rattlesnake skin and mountain-lion's tail. He takes them and prays to rattlesnake and mountain-lion for their powers. War expedition is given up and man neglects to throw away skin and tail. Long time afterward Red-Mountain-Lion one morning hears turkey cackling. He goes to catch it and hears rattlesnakes by his side. As he does not return, brother goes for him. He is found unconscious and scalped. Tracks of mountain-lion are found. Medicine-man comes and tells brother to return animal's gifts to the woods, where Red-Mountain-Lion had found them. Man obeys, and then takes brother to creek and bathes him. Red-Mountain-Lion recovers, but is always foolish. He becomes more foolish in old age and does many evil things, and so is killed.

43. BUFFALO WOMAN.

Cannibal has handsome son who will not marry. He is called Braveness for his bravery in hunting. He goes hunting and sees young and beautiful woman sitting under elm tree. She calls him and says she has come to meet him. She asks him to take her to his home to be his wife. They start for his home at once, and old people let girl become son's wife. They live happily together for long time. Then girl asks him to do whatever she asks. When he promises, she asks him to go with her to her home. They start, and when they come to high hills, she says her home is on other side, and that people will bother him, but he is not to get angry. If he does, young men will kill him, as they are jealous of him. She then asks him to lay on ground and roll over twice. He does so, and is changed into Buffalo. Then woman does same, and becomes Buffalo. When they reach top of hill, they see thousands of Buffalo. They are woman's people. Braveness follows woman until they come to old Buffalo cow, her mother. They stay long time, and as young Buffalo bother Braveness, they go back to his home. On way they become human again. Woman asks man to say nothing about transformation. They stay at home a year, and then decide to go and see woman's mother. After living with Buffalo long time, wife tells husband old people are thinking of killing him. He is to run in foot race. He is worried and goes out for walk. Unknown person tells him if he is beaten at running, he is to be killed, and so he is going to help him to win. He gives Braveness medicine root, which he is to throw behind him when one catches up with him, and he will leave him long way behind. Then he gives Braveness mud to throw behind him when second man overtakes him, after which he will soon be at stopping place. There person will meet him. Next day is day of race. Old Buffalo takes him to place where runners start. Young Buffalo make fun of him, but he places himself in their midst. Braveness leaves Buffalo long way behind at start, but they gain on him. He throws root, and he is far ahead again. He gives out and one Buffalo gains on him. He throws mud, and he is far ahead again. When nearing goal Buffalo is about to catch up with him, when heavy wind comes up and keeps Buffalo back until he reaches goal and wins race. He knows it is Wind who has saved his life. After race, no one molests him again. Afterward he and wife go to live with his people. When child year old, they go again to see wife's people. They remain three years, and then return to Braveness' home. Mother will not let child go out to play with other boys. He slips away and joins boys. They play buffalo, and when little boy rolls over twice, he gets up real buffalo calf. Boys run, and mother seeing them, goes out and finds son changed into buffalo calf. She runs down hill with him, becomes buffalo, and they run away before husband comes from hunting. He can not find his wife and son, and some one tells him what has happened. He does not believe story until he sees their tracks. He never hears of them again.

44. THE GIRL WHO MARRIED WILD-CAT.

Beautiful girl refuses attention of young men. Handsome youth comes and talks with father and brother, but pays no attention to her. Girl dreams of him when asleep; sees him coming to her. She awakes and hears faint noise. She closes eyes and prays that dream may come true. She opens eyes and young man is bending over her. He begs her to go with him and she does so. When long way from home man tells her he is Wild-Cat, but she refuses to go back. They climb high mountain, and Wild-Cat leaves girl to fetch his grandfather Wild-Cat. Girl's brothers overtake them, and want to fight Wild-Cats, who are dressed like men. Sister cries and promises brothers she will soon return home. They go back and father is very angry. He goes in search of daughter and wanders about until he dies.

45. THE WOMAN WHO TRIED TO KILL HER SON.

Abut has wife and boy seven years old. He is always hunting. Wife dislikes boy and abuses him. She digs deep hole and throws him in, putting brush over it. Abut returns and asks for son. She says she has been looking for him all day. They look for him several days and can not find him. Boy grows hungry and cries. Coyote comes, helps him out of hole, and takes him to Coyote's home. He remains several years; then he tells Coyote he wants to go and see his father. He says he will tell father what happened, and that they will go on buffalo hunt, and that Coyote and family are to kill mother when she brings them meat. Coyote lets boy go home. He tells father what he is going to do with mother. Next day they go hunting and kill buffalo. While woman is cooking supper they hear Coyotes howling. After supper boy tells mother to get meat and come with him to feed Coyotes. She carries meat on back. When near Coyotes, boy pushes her down and Coyotes jump upon her. Father and son live together many years.

46. THE JEALOUS HUSBAND.

People go on war-path and spies are sent out to locate enemy. Leader chooses for spies two who are very close friends and always go together. One is married and other single. One day they come to high hill. They climb it and find on top big hole, like well, with water. Married man tells friend to go down in hole to get some water. He descends on long buffalo-hide rope. Instead of pulling him up again his friend throws rope into hole and goes away. He starts for camp and tells head man that his friend was killed by enemy who pursued them. Camp therefore breaks up and people return home. Man in hole asks birds passing over to take him out, but they take no notice of him. After nine days Buzzard flies over hole and man again asks for help. Bird passes again and again, and fourth time lights on ground. He peeps over rim of hole and tells man he will help him out, but he must first go for some medicine. Buzzard goes away, but comes back and flies to bottom of hole. He tells man to shut his eyes and take step forward. He is then on back of Buzzard, who flies upward out of hole. Bird takes man to home of Buzzard, and there he remains until he can walk around. Buzzard tells him his friend maltreated him because he had been told he was going to take his wife away. He then says he is going to take man home, and tells him what to do there. They start and Buzzard tells man to shut his eyes. When near home he gets off Buzzard's back and goes to his lodge. He tells how his friend had beaten him and how Buzzard had rescued him. He then sends his sister to fetch friend's wife. Woman returns with sister and stays with man, refusing to go back to former husband. Afterward, whenever they go on buffalo hunt, husband kills one buffalo first, cuts it up, and scatters meat; then he kills another one and takes meat home. When asked why he did that, he will not tell; but once his uncle comes and asks him, and he says he had lived with woman many years and when he dies she shall drop dead, too.

47. THE TURTLE WHO CARRIED THE PEOPLE.

People travel about looking for village site. They come near big water and see what they think is large rock. They make village near rock, which they use as dancing place. After some time crier announces big dance. While all people are dancing on rock it begins to move. They see big head and legs appear from under it; then they know they are on big turtle. They try to get off, but their feet are stuck tight. Turtle carries them into water and drowns them.

48. WHY DOGS HAVE LONG TONGUES.

When animals were like people, dogs were noted for telling everything they knew. Running-Water is great hunter, and wants dog to help him who is not tattler. He tries to teach young pup not to talk so much. When big enough, Running-Water takes it to hunt small game. Every time man kills game, dog sneaks home and tells, returning circuitous way, as though he has been hunting all time. After time Running-Water goes for long hunt and takes dog with him. They kill many big animals and start for home. Running-Water misses dog and returns to camp for him. Dog is not there, and when Running-Water gets home he finds dog. He has told many big stories about animals they have killed. Running-Water is very angry and gives dog good whipping. He then catches hold of dog's tongue, pulls it as hard as he can, and then runs stick across his mouth. Since then dogs have long tongues and big mouths.

49. WHY HAWKS HAVE THIN LEGS.

Chicken-Hawk is poor hunter. He meets Eagle, and, pretending he has killed many big game before, asks him if he will help him to kill antelope. Eagle promises on condition he can have half meat. Hawk goes home and tells family he has shot antelope in head and is going in morning to kill him. Hawk and Eagle go hunting together and find antelope in mountain. Eagle kills it and they divide meat. Hawk takes meat home and tells family he has given part of meat to poor hunter who had never tasted antelope. Family tell every one what good hunter Hawk is. Friend visits him to see if reports true. Hawk hunts all day and returns with only mouse, which friend refuses to eat. He hunts next day and can not find anything. He is so ashamed that he cuts meat off of his legs to take home for friend to eat. This is why hawks have no meat on their legs.

50. THE POWERS OF BUFFALO AND BEAR.

Once, when animals understood one another, Bear and Buffalo met. They told each other of their powers. Bear says he was once human being and went with people. One night he dreamed that he became Bear and that human being was pursuing him and shooting him with arrows. When he awoke he found all was true. He left people and began new life in mountains and woods. Buffalo then speaks and says he, too, was like human being. His people were called Buffalo after oldest chief. When people began to enter this world Buffalo people were forbidden to enter, because some one had made mistake. They found out it was Coyote, and they prayed that Father would give him powers, so that he could enter world and take them along. They had to change into wild animals, and for love of people to be their game. Then they were given powers to be dangerous and horns to fight with. Then Bear asks Buffalo to show what he does when he wants to hurt or kill any one. Buffalo watches him, and before he knows what has happened he is falling to ground and Buffalo is coming at him again. Buffalo asks Bear if he saw him when he first started after him. He says, "No," and Buffalo asks him to show how he uses his powers. Bear walks back and forth looking at Buffalo with angry eyes, then moves slowly toward small tree, which he grabs and cuts down with his sharp teeth, and before Buffalo knows, Bear is upon him, and he is trying to get up from ground. Bear holds him down until he is ready to give up. When Bear lets him go they part and go to their homes.

51. HOW RABBIT STOLE MOUNTAIN-LION'S TEETH.

Rabbit, in absence of grandmother, goes to house of Mountain-Lion. He is not at home. Rabbit finds Mountain-Lion's teeth and takes them home. Rabbit tells grandmother Mountain-Lion will come after his teeth and they must fool him. He tells her to build fire outside of door and put on it kettle of water, and to put some stones into water and boil them. When Mountain-Lion comes she is to tell him that she is boiling stones for "Chief of all the beasts," who is Rabbit's guest. Mountain-Lion comes, and when he hears what grandmother says, he runs away as fast as he can.

52. RABBIT AND THE DANCING TURKEYS.

Rabbit and Wild-Cat meet and begin to fight. To save his own life, Rabbit says he will show Wild-Cat how to catch Turkeys. He tells him to stand still while he sings Turkey dance song. Rabbit sings, and then tells Wild-Cat to lie down and pretend to be dead. Turkeys hear song and come to see what it is about. Rabbit tells them he has killed Wild-Cat and they are to dance victory song. Turkeys dance and Wild-Cat jumps up and grabs big Turkey. As he does so Rabbit runs away and escapes.

53. ADVENTURES OF COYOTE.

In beginning of world people held councils to decide about things. Question comes up, what kind of rain there shall be. Rain in form of lead balls is proposed. Coyote objects, as lead would be dangerous, and suggests drops of water. This is accepted. Coyote goes traveling and comes to place where great powerful Bear lives. Bear says if he is Coyote he will kill him. Coyote pretends to be son of powerful medicine-man. Bear decides to kill him, and Coyote tells Bear to wait until his father sees him. This is at sunrise, when Sun peeps over hill. Coyote says Bear can kill him, as father is watching him. Bear thinks Coyote must be great man and becomes frightened. He gives Coyote many things to eat. Long after, Bear discovers that he has been deceived and tries to find Coyote's home to kill him, but without success. Coyote moves from place to place and meets Mountain-Lion near lake. He tells him he is very hungry, and they go together to lake. Mountain-Lion climbs the tree and tells Coyote to hide. Wild horses come to water, and Mountain-Lion jumps and kills young horse, which they have for dinner. Mountain-Lion teaches Coyote how to kill horse. Next day he does so. Mountain-Lion tells him not to try to kill three or four year old horse. Coyote leaves his friend and next day goes to lake and thinks he will try to kill largest horse. He jumps from tree on large horse, which throws him off and kicks him under jaws. Mountain-Lion comes and Coyote asks him what he is laughing about. Coyote is not able to move for a long time and then leaves place. He hears some one in persimmon tree and finds Opossum eating persimmons. He asks Opossum for some, but Opossum laughs at him. While pretending to fall from tree, limb breaks and Opossum comes to ground. Coyote gives him good beating and leaves him to die. Opossum fools him, and when Coyote goes away Opossum climbs tree again and laughs at him.

54. COYOTE ESCAPES AN IMAGINARY FOE.

Coyote goes hunting buffalo. He sees Turkey on top of tall tree and threatens to kill him if he does not get down. Turkey starts out toward prairie, as Coyote says he has no power to kill anything on prairie. When Turkey comes to ground Coyote catches up with him and kills him. While eating Turkey, Coyote looks around to see that no one is watching him. He thinks he sees somebody standing behind him, making motions as if to strike him. He starts to run, every now and then looking back to see if he is out of reach. He thinks he sees man right after him, ready to hit him, and runs with all his might. Coyote was given power at beginning of world to run without decreasing his running powers. He has run eight times, and ninth time he runs farther than usual. Again he looks around and thinks he sees man about to hit him. When running tenth time his powers are decreasing, and he dodges from right to left to fool man. Coyote gives out when running twelfth time. He turns on his back and begs not to be killed. He falls over on his face and hears something crack. It is turkey feather, which had stuck between his teeth and is nearly straight up above his right eye. He finds he has been fooled by turkey feather and is very angry. Ever since he has looked wild, and when he runs first looks around to right and then to left to see if anybody is near him. When he reaches home Coyote says he has killed Mountain-Lion.

55. COYOTE GOES FISHING.

Coyote goes hunting along river and meets man carrying fish. Coyote asks him how he got fish. Man, who has been tricked by Coyote, tells him to go to edge of river in evening and stay until he comes to see him. Coyote goes and finds man waiting for him. Man tells Coyote to sit by edge of water while he breaks ice. Coyote does as man tells him and sits by bank fishing all night. Water freezes on Coyote's tail, and in morning he can not move. Man comes and asks if he is catching any fish. Coyote says he thinks he has caught two or three, and asks man to help him to land them. Man reminds Coyote of his trickery and tells Coyote he is going to kill him. Coyote denies trickery and offers to go and bring one that man is looking for. Man goes to lodge for bow and arrows, and on return sings death song, and then shoots and kills Coyote.

56. COYOTE HUNTS GEESE.

Coyote once man. People dislike him and call him coward, as he is always trying to cheat some one. He visits his best friend and finds he has been feasting on white geese. Coyote asks friend where he got them. Friend tells him to come back in evening and he will show him where geese come. When Coyote is out of sight, friend carries ashes from fire and forms them in shape of geese near lake. Just before evening he goes and puts coals under ashes. Coals burn up, but fire can not be seen from outside. When Coyote comes they go to place, friend taking lead. He pretends not to see first pile of ashes. When Coyote sees it he prepares to jump, and friend laughs. Coyote pays no attention, but jumps on pile of hot ashes and burns himself. He runs away, but is burned so badly that he runs until he kills himself.

57. COYOTE IMITATES HIS HOST.

In old days, when animals talked and visited each other, Coyote and Raven were great friends. Coyote, weary of hunting without success, goes to Raven, who has control of buffalo. Raven, seeing Coyote sad and silent, shoots arrow into air and waits for it to come down. It pierces him under right arm. He draws arrow out, and with it comes buffalo meat and fat. He gives meat to Coyote, who eats heartily. Before he goes he invites Raven to visit him. Coyote makes bow and arrows and puts them away until Raven comes. Raven pays Coyote visit. After talking, Coyote says he has no food, but will soon have some. He takes bow and arrow; shoots arrow into sky. When it comes down it strikes him in thigh. He runs away, screaming with pain. After waiting a while Raven goes home without any meat, but much amused at Coyote's performance. Coyote's friends wonder what has become of him, but he grows very hungry, and not finding any food he goes to visit Black-Mountain-Bear. Bear regrets to have no food, but leans against persimmon tree and ripe fruit falls to ground. Coyote eats many, and before going insists that Bear come to see him. Coyote can not find persimmon tree with fruit on it.

He cuts down tree without fruit and takes it home, where he sets it up. He then takes persimmons he has stolen from Bear's home and others he finds and places them all over tree as though they have grown there. Black-Mountain-Bear goes to visit Coyote, who bumps head against tree, but persimmons will not fall. Finally he arises and gives tree big shake with hands, and it falls over, hitting him on head. He pretends not to be hurt and gathers up fruit for Bear. Bear can hardly swallow for laughing, as Coyote's head keeps getting bigger and bigger. Bear soon goes, and Coyote holds his sore head, but is happy for having furnished food for Bear.

58. COYOTE IMITATES HIS HOST.

Coyote, looking out for something to eat, comes to grass lodge. He enters and sees man walking about with light on his head. Coyote calls out to him that his head is on fire. Man smiles and says he has always worn light, and it will not burn anything. Man is Woodpecker. He gives Coyote something to eat. Coyote goes, after eating as much as he can, and asks Woodpecker to make him a visit. Some time afterward Woodpecker goes to Coyote's lodge and is surprised to see im with big bunch of burning straw on his head. Woodpecker tells him to take it off, but Coyote says he always wears it at night. As he finishes speaking, his hair catches fire, and he runs out of lodge screaming for help. Woodpecker waits for his return, but he does not come.

59. COYOTE, THE DEER, AND THE WIND.

Coyote meets Deer, who asks him how he kills his game. Coyote replies he can kill anything he can lay his hands on. Deer tells Coyote if he can catch Deer he may kill and eat him. Coyote tries to catch Deer, but without success. One day, after trying to find him asleep, he lays down in grass to take nap. When he awakes, he hears some one singing near by. He is frightened and peeps about, but sees no one. He hears his name mentioned in song, and jumps up and runs as far as he can; then he drops to die. He hears voice again, and it says that he is Wind, and is going to give Coyote power to catch Deer. Coyote arises and barks thanks. He starts out to find Deer and travels all day, but can not find him. He comes to camp where he steals buffalo robe. He puts robe over him, and goes on to look for Deer. He thinks he sees him near river, goes round another way to get close, and grabs him. To his surprise, he has man whose robe he has stolen. Man takes Coyote home and makes him work for him and his sister, treating him cruelly because he has stolen robe. One time while man out hunting, Coyote makes sister pack her clothes and go away with him, saying her brother is killed. They start for Coyote's home. Coyote goes behind girl, and whenever she stops or falls hits her with stick. Man returns, and finds sister and Coyote gone. He starts after them and soon catches up with them. He shoots arrow in front of sister. She sees it and knows her brother is coming to help her. She cries for joy and Coyote whips her. Man goes on hill and shoots another arrow. Coyote sees man and is frightened. He pretends to be kind to girl, and tries to deceive man when he comes down hill and asks where Coyote is going with sister. Man makes Coyote put bundle of clothes on his back, and tells sister to sit on bundle. He puts bow-string through Coyote's mouth and gives ends to girl. She saws string back and forth, and man runs alongside of Coyote, whipping him, thus returning home. Man is Wind, who has become angry at Coyote for stealing his robe and trying to catch Deer with it, instead of waiting for power.

60. COYOTE DIVES FOR MEAT.

Coyote kills big deer, which she hides in tree while she goes for her children. Wild-Cat sees her, and when she has gone, steals meat and climbs tree on bank of river. Coyote returns with children, but can not find meat. While children are abusing her she sees reflection of meat in water and thinks it is meat. She dives into water and reaches for meat, but can not get it. She ties stones about her neck and dives again. Coyotes wait long for mother, and after a while they see excrement on water and think it is meat. They laugh, and Wild-Cat laughs at them. They look up and see Wild-Cat and meat in tree. Wild-Cat tells them that mother is drowned. They cry, and Wild-Cat climbs down and gives little Coyotes all they want to eat and takes them home. He cares for them until they are grown.

61. COYOTE, THE GEESE, AND THE WOODPECKERS.

Coyote, returning home after unsuccessful hunt, hears laughing and playing. He runs over hill, and on other side is big lake, with several white geese playing on surface. Coyote watches them from bushes until he thinks of plan whereby he can catch them. He limps out from bushes, pretending he has been hurt. Geese hear him and swim out into water. One then asks Coyote what is the matter, and he answers that he will be killed if he does not get across water, and then all rivers and lakes will dry up. Geese know that Coyote is lying and decide to take him and throw him into deep hole. Old Goose tells Coyote to get on his back. Coyote at first objects, but at last does as he is told, and Goose flies up in air. Other Geese follow and take turns in carrying Coyote. They fly over timbered country away from lake and drop him into hollow trunk of tree. He can not get out, and is frightened almost to death. Fly comes and Coyote prays to him for power. Fly goes and brings Woodpecker, who, finding Coyote really wants to get out, fetches some of his brothers. They peck big hole in tree. Coyote tells them to stick their heads in and see if he can really get out, and then bites their heads off. After he has eaten Woodpeckers, Coyote escapes.

62. COYOTE AND RABBIT KILL A BUFFALO.

Rabbit hunts for food, and one day goes far away without finding any game. He is going home playing and singing when Coyote sees him. Coyote steps behind Rabbit, yells "Bo!" and makes grab for him. Rabbit is frightened, but tells Coyote not to kill him, as he knows where is good fat buffalo. Rabbit leads way to where old buffalo stands. Rabbit tells Coyote to climb into animal. Coyote obeys, and Rabbit follows. They then begin to eat buffalo's side, and soon it falls dead. Old man comes and begins to butcher buffalo. Rabbit tells Coyote to hide in intestines, and he hides in bladder. Old man places intestines on one side, but throws bladder in bush, where Rabbit crawls out and escapes. Coyote is discovered and killed.

63. COYOTE, MOUNTAIN-LION, AND RABBIT.

Coyote hears crying like child. He finds Mountain-Lion's den and young there alone. He is hungry, and kills and eats them all. Mother comes back with food for young and can not find them. She follows Coyote many days, and when sitting on bank of river to rest sees Rabbit. She calls him and asks him to help her to capture Coyote. They go along river together and find deer. Mountain-Lion kills it. When they have butchered it she tells Rabbit to cover her face with fat and then put deer on her back. Rabbit then gets on top of deer. While crossing prairie some one calls out asking Rabbit where he got his fine horse. Rabbit pretends not to hear, and voice again calls to him. Rabbit goes on until Coyote catches up with him and tells him to get off, as horse is his. Rabbit jumps off, and as Coyote is about to get on he stops to bite piece of fat off its face. He recognizes Mountain-Lion and starts to run. Mountain-Lion springs upon him and kills him.

64. COYOTE BECOMES A BUFFALO.

Coyote meets Buffalo and asks him for power to turn into Buffalo and eat grass. Buffalo consents, and tells Coyote to stand facing other way and not to move. Buffalo throws up dirt with hoofs and makes plunge toward Coyote, who jumps out of way. This is repeated six times, but seventh time Coyote stands firm and Buffalo throws him up into air. When he comes down on feet he is very young Buffalo. He begins to eat grass at once. Old Buffalo tells him he can become Coyote again by rolling over two or three times in Buffalo wallow. He cautions him that power is good for only seven times, and that he must not give power to any one else. Buffalo then makes him change back into Coyote and leaves him. Coyote soon begins to try his power, and before meeting any one has tried it six times and has turned into Buffalo seventh time. He meets Coyote and asks him if he does not want some of his power. He tells him to stand facing other way with eyes shut. He starts at him and at last attempt they both go into air and they both come down Coyotes.

65. COYOTE AND THE TURKEYS.

Coyote is looking for something to eat and hears voice. He goes and finds Turkeys having fun by getting into sack and rolling down hill. Coyote lets Turkeys roll him down hill several times. Then he tells Turkeys to get into sack and he will roll them down. All crawl into sack and Coyote ties it fast at each end and starts for home with it. He calls his four sons and takes Turkey out of sack. He tells sons to build big fire and they will have feast. They go to timber for wood and leave sack in charge of youngest son. Coyote tells him not to untie strings. Young Coyote unties strings and looks into sack to see what Turkeys are doing. Turkeys all run out and fly away. He does not know what to do, but finally fills sack with dirt. Father returns and says they will have fine feast. When he opens sack he finds only dirt. He is very angry and kills young son and eats him instead of Turkeys.

66. COYOTE'S EYES ARE REPLACED BY BUCKEYES.

Coyote is hunting and hears voices. He thinks they are turkeys making noise and goes to catch them. He finds Ducks playing in water and they ask him to join them. He consents to play at taking eyes out. First Duck has eyes taken out, then he dives into water and his eyes are thrown after him. When he comes up he has them in place. All Ducks take turns. Then Coyote goes through same performance and comes out all right. Ducks have power to do almost anything, but to do it only once. Coyote wants to try trick again, but Ducks object. At last they take his eyes out and he dives into water. Ducks all fly away and leave

Coyote. He goes along talking and crying. Man finds him and goes to get something to make him new eyes. He returns with green buckeye balls. He hits place of right eye with buckeye ball, and then place of left eye with another ball, and Coyote's eyes are restored.

67. COYOTE AND TURTLE RUN A RACE.

Coyote, returning from unsuccessful hunt for game, passes home of Turtle. Turtle invites him in and offers him something to eat. Turtle is tired and says he has just come back from races. Coyote and Turtle arrange to have race two days hence. Coyote sends son to announce race to Coyote people and tell them to bet heavily, as he would defeat Turtle. Turtle sends son to announce race, and that best runners are to come to his lodge. They come, and Turtle asks them to help him to cheat Coyote out of race. Each is to put white feather in his hair and to paint himself to look like Turtle. They are to station themselves at intervals along course. One is to start with Coyote and when far behind is to drop into grass. Then next one is to jump up and run, then next one, and so on until last. Turtle will be last and beat Coyote over goal. On day of race Turtles station themselves along way in tall grass. Coyote comes and wants to run short distance, but Turtle insists on long distance. Many Coyotes come and bet on Coyote. They start and Coyotes laugh, for their man is far ahead. Soon to their surprise Turtle is ahead. Coyote overtakes Turtle, and they laugh again. They hear Turtles cheering and Turtle is far in lead. The race then goes on, and just as Coyote has passed Turtle and is near goal, Turtle crosses line and all Turtles set up loud cheer. Coyote runs off in grass and is wondering yet how Turtle beat him. All other Coyotes are angry because he makes them lose so many bets.

68. COYOTE, WILD-CAT, AND THE OLD WOMAN.

Old blind woman lives alone. She always has plenty to eat. Whenever she sits down to eat she speaks as though talking to some one. Wild-Cat smells meat and goes in. He sees old woman is blind and slips quietly to corner. She speaks, but then begins to eat; so Wild-Cat slips over and begins to eat, too. He is careful not to make noise, and when little left in pot quietly slips away. He comes there every day and grows sleek and fat. Coyote meets him and asks where he gets so much to eat. Wild-Cat tells him and agrees to take him, on his promise to keep very quiet. They go and sit near door while meat cooking. They steal meat out of pot. Coyote forgets all about keeping quiet and cracks bone so loud that old woman jumps up. Wild-Cat gets out of house. Old woman runs to door and closes it. She takes long spear and pokes around room. Spear pierces Coyote. He cries out with pain, and she continues poking until she kills him. Wild-Cat comes next day and finds Coyote dead. He is sorry, because he is afraid to go to house again to eat.

69. COYOTE CHALLENGES THE SNAKE.

Coyote goes from place to place to find Snake. He stops to rest and soon hears some one calling him. Snake comes up, and Coyote, after referring to Snake's supposed power, says he wants to see which of them has most power. Snake agrees and suggests that they bite each other once. Coyote says snake is to bite first. Snake goes up to Coyote and bites him on top of nose. Coyote asks if that is all Snake can do, and says he will show his power. He comes to Snake and bites him nearly in two. They go little way off and lie down. Coyote calls to Snake and hears him answer in low voice. Snake then calls to Coyote, who answers with big voice. They keep calling to one another all night. Toward daylight Snake calls Coyote and no answer comes. After calling fourth time, Snake goes to see what is the matter and finds Coyote all swollen and dead.

70. COYOTE TURNS INTO A CORN MILL.

Women make corn mills from trunk of old tree. There are many such mills, but one very old and smooth, women like best. Woman pounds corn in old mill and when ground she sees she has only little. She watches other women and corn disappears in same way. They examine mill and woman suggests that they cut it with axe to see where corn has gone. Mill falls over and Coyote jumps up and runs away. He has turned into corn mill, so that he can get all he wants to eat.